# State of The Great Lakes 2001

Environment Canada
and
United States Environmental Protection Agency

ISBN 0-662-30488-8
EPA 905-R-01-003
Cat. No. EN40-11/35-2001E

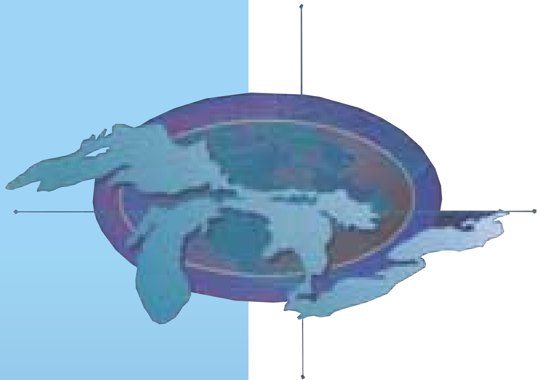
The *State of the Great Lakes 2001* carries the Canadian State of Environment (SOE) reporting symbol, because this report satisfies the guidelines for the Government of Canada's SOE reporting program. The two purposes of SOE reports are to 1) foster the use of science in policy- and decision-making and 2) to report to Canadians on the condition of their environment. *The State of the Great Lakes 2001* 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 amongst issues.

Photo credits:
Blue Heron, Don Breneman
Sleeping Bear Dunes, Robert De Jonge, courtesy Michigan Travel Bureau
Port Huron Mackinac Race, Michigan Travel Bureau
Milwaukee River, Wisconsin, Lake Michigan Federation

# State of the Great Lakes 2001

*by the Governments of*
**Canada**
*and*
**the United States of America**

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



# A Promise to Future Generations

Created by the student delegates of the 2001 Great Lakes Student Summit
May 9-11, 2001
Buffalo, New York

*We, the students of the Fourth Biennial Great Lakes Student Summit, embark on the new millennium with this solemn and heartfelt promise:*

*We promise to continue our quest for knowledge related to the Great Lakes and the environment.*

*We promise to support recycling efforts and encourage our friends and family to recycle and reduce waste.*

*We promise to join in community clean-ups, beach sweeps, tree plantings and other restoration efforts.*

*We promise to reduce our use of energy and natural resources and encourage those around us to do the same.*

*We promise to practice water conservation, pesticide reduction and other environmentally friendly practices and convince our families and peers to join our efforts.*

*We promise to make others aware of the problems of the Great Lakes and try to convince them to work towards addressing these problems.*

*We promise to protect the habitats around the Great Lakes, especially wetlands and other environmentally sensitive areas.*

*We promise to make political leaders more aware of environmental issues and concerns, so that we can keep the Great Lakes healthy for generations to come.*

*We promise to encourage stronger and more meaningful cooperation among the Great Lakes states and the Province of Ontario.*

*We promise to put the needs of the Great Lakes and the environment before our own personal needs.*

*We promise to make a conscious effort to respect all living and non-living components of our watershed.*

*Finally, we promise to give back to the Earth more than we take from it.*

# Table of Contents

# Executive Summary

This State of the Great Lakes (2001) report is the fourth biennial report issued by the governments of Canada and the United States of America (the Parties to the Great Lakes Water Quality Agreement), pursuant to reporting requirements of the Agreement. Previous reports presented information on the state of the Lakes based on ad hoc indicators suggested by scientific experts involved in the State of the Lakes Ecosystem Conferences (SOLEC). In 1996, those involved in SOLEC saw the need to develop a comprehensive, basin-wide set of indicators that would allow the Parties to report on progress under the Agreement in a comparable and standard format.

Indicators will tell us whether we are meeting the goals of the Great Lakes Water Quality Agreement *("...to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem")*, and provide us with answers to 'simpler' questions such as: Can we drink the water?; Can we eat the fish?; and Can we swim in the water? Indicators help us to measure our progress towards reaching our goals, or, alternatively, how far we have left to go.

This report represents the first in the indicator-based format, giving information on 33 of the 80 indicators being proposed by the Parties. These 33 indicators were selected because data for them were readily available with the individual indicator reports prepared by subject experts.

Not all of the proposed 80 indicators are presently being monitored. This situation represents a challenge to the Parties to ensure that information is available in a timely fashion to allow reporting on progress on all indicators, at a frequency suitable for each indicator. It is essential that monitoring systems be put in place to ensure collection of all essential information applicable to each indicator.

A full description of the indicators is in the ***Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 4***.

The Parties cannot provide a detailed quantitative assessment of all aspects of the State of the Lakes based on 33 of 80 indicators. Nevertheless, the Parties make the following overall qualitative assessment:

**The status of the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem has been assessed and is considered mixed because:**

- **Surface waters are still amongst the best sources of drinking water in the world;**
- **Progress has been made both in cleaning up contaminants and in rehabilitating some fish and wildlife species;**
- **Invasive species continue as a significant threat to Great Lakes biological communities;**
- **Atmospheric deposition of contaminants from distant sources outside the basin confound efforts to eliminate these substances;**
- **Urban sprawl threatens high quality natural areas, rare species, farmland and open space; and**
- **Development, drainage, and pollution are shrinking coastal wetlands.**

The assessments for each of the 33 indicators are on the following page. The section that follows the Executive Summary contains implications for managers. This section was prepared in order to meet one of the SOLEC objectives: "...to strengthen the decision-making and environmental management concerning the Great Lakes."

| Indicator Name | Indicator ID # | SOLEC Category | Assessment * |
|---|---|---|---|

*See page 25 for definitions

# Implications for Managers

This report presents a subjective assessment, based on best professional judgment, of 33 of 80 indicators of ecosystem health. One of the objectives for using indicators to assess the status and trends of Great Lakes ecosystem components is *" . . . to strengthen the decision-making and environmental management concerning the Great Lakes."* The material presented in this report leads to certain inevitable implications for environmental and natural resource managers. These implications can be grouped into two major categories: those that relate to the development and use of indicators and those that relate to management of the Great Lakes basin ecosystem.

## Indicator Development and Use

**Indicator Development and Testing.** Many of the indicators presented in this report were not fully implemented, and many more were not presented because they have not been sufficiently developed and tested. To provide an assessment of the Great Lakes based on all the indicators that are necessary and sufficient, further work on the indicators will be required.

**Setting Endpoints.** Many of the indicators do not have an associated endpoint, target or reference value that establishes when the designation "good" can be applied to the ecosystem component being assessed. Some can be determined through planning exercises such as LaMPs and RAPs, but for others, specific research may be needed. Until such endpoints are provided, however, assessing an indicator will still be useful as it will show trends (i.e. is the condition getting better, worse or staying the same).

**Monitoring, Data Collection.** Without consistent monitoring or other data collection techniques directed to the suite of Great Lakes indicators, an assessment of the state of the Great Lakes basin ecosystem health will be incomplete. This issue is fundamental to measuring progress toward the goals of the Great Lakes Water Quality Agreement. Consistency in monitoring programs is important in geographic scope, timing and methods.

**Data Quality.** The quality of data collected and reported is important in order to influence environmental management decisions. Poor quality data can lead to erroneous conclusions about the environment and result in wasted or ill-advised managerial actions.

**Information Management, Databases.** Because multiple jurisdictions are involved in monitoring and data collection in the Great Lakes basin, the data are scattered widely. As the suite of indicators becomes more fully implemented, the effort required to assemble, analyze and summarize all the data may become a challenge. A deliberate system of information management for Great Lakes indicator data will facilitate rapid and accurate distribution of indicator information to environmental managers, decision makers, and other interested people.

**Commitments and Ownership.** For state of the Great Lakes reporting to be sustainable, commitments are required for agencies to accept lead roles to collect and interpret data and report on selected indicators prior to each State of the Lakes Ecosystem Conference (SOLEC). Data for some indicators are distributed amongst several agencies. Some agencies have accepted responsibility for preparing biennial indicator reports, and some are considering to which indicators they can commit and to which they can contribute. Many of the indicators still await "adoption," however.

## Environmental Management and Programs

**Non-native Species Control.** In addition to causing severe disruptions to the food web, the introduction and establishment of many non-native species into the Great Lakes basin has severe negative economic consequences. Decreased spending for sport fishing and other recreational opportunities, increased costs to industry for infrastructure, and altered management plans can be anticipated as non-native species displace native ones. Non-native species control is a priority issue. Implementation and maintenance of effective control programs will reduce the risk of further invasions.

**Source Controls: Point, Non-point, Agriculture, Atmospheric Emissions.** Continuing loadings of contaminants and nutrients remain a problem in many areas of the Great Lakes. Sources may be point or non-point, and they may involve industrial, agricultural, municipal or other sectors of the economy. In all cases, diligence toward controlling all the sources will facilitate progress toward the goals of the Water Quality Agreement.

**Drinking Water.** Although the Great Lakes themselves are a good source of treatable drinking water, diligence must be taken to ensure proper treatment, and to minimize the possibility of contaminants entering the distribution system. In addition, consideration of the quality of other sources of water within the basin must be examined (i.e. river and ground water).

**Infrastructure, Maintenance.** Much progress has been made to reduce the quantity of contaminants and nutrients entering the Great Lakes, in part through the construction and maintenance of sewage treatment facilities, industrial processes to reduce waste, and other physical solutions. This infrastructure requires maintenance to continue efficient, effective operations.

**Technology Development.** Some Great Lakes problems continue to be unresolved in part because of inadequate technology, e.g., complete remediation of in-place contaminated sediments and zero discharge of toxic chemicals within the Great Lakes basin. Aggressive pursuit of new devices, systems and/or methodologies will hasten progress toward the virtual elimination of toxic substances in the Great Lakes basin ecosystem.

**Restoration, Protection Programs.** The overall goal of the Great Lakes Water Quality Agreement is to *"restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin."* Administrative programs such as ecological preserves, zoning restrictions, parks, wildlife refuges, etc., help to maintain natural features. The application of such controls toward wetlands and terrestrial features is important for the restoration and maintenance of Great Lakes ecosystem components.

**Human Population Impacts.** Human populations greatly influence and modify the Great Lakes basin ecosystem. Although the problems observed in the Great Lakes can be traced to human origins, particular attention to societal pressures such as urban sprawl, energy consumption and climate change may help to reduce potentially adverse impacts.

**Emerging Issues.** Not all issues and concerns about the Great Lakes have been anticipated in the Great Lakes Water Quality Agreement and other planning documents. Diligence in monitoring and timely communication of findings will help ensure that government agencies and other organizations identify emerging issues quickly so that environmental management activities can be implemented. New issues may be chemical (e.g., endocrine disrupting chemicals), biological (e.g., disappearance of *Diporeia* from many lake areas), or physical (e.g., effects of water level controls).

**Environmental Research.** The best managerial activities are based on the best understanding of the structure and functioning of the ecosystem being addressed. Fundamental research into ecosystem processes and the impacts of new or continued stresses will assist environmental managers to best allocate resources toward resolution of identified problems. Similarly, environmental management objectives will help direct basic research toward an understanding of critical ecosystem processes.

**Climate Change.** Climate change scenarios have been developed for the Great Lakes basin. Projected climate changes will impact both ecological and economic systems. For instance, the possibility of lower water levels will have an impact on coastal wetlands, aquatic habitat and the shipping industry. A potentially warmer and drier climate will impact agriculture, the recreation industry (skiing) and the migration of species northward. Management plans need to be developed with these scenarios in mind.

# Section 1
# Introduction

The State of the Lakes Ecosystem Conference, or SOLEC, has its roots in the Great Lakes Water Quality Agreement, and its overall purpose:

> *"… to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem."*

The revisions to the Agreement in 1987 established what are now well known concepts and programs such as Beneficial Use Impairments, Remedial Action Plans for Areas of Concern, and Lakewide Management Plans.

Also in the Agreement, however, is the commitment by the two Parties for regular reporting on progress toward several of the general and specific objectives. The State of the Lakes Ecosystem Conferences were established by the governments of Canada and the United States in 1992 in response to those reporting requirements. The conferences were to provide independent, science-based reporting on the state of health of the Great Lakes basin ecosystem every two years.

Four objectives were established for the conferences:

- *To assess the state of the Great Lakes ecosystem based on accepted indicators.* SOLEC facilitates a rational, disciplined approach toward assessing the various components of the Great Lakes ecosystem and reporting the findings.

- *To strengthen decision-making and environmental management concerning the Great Lakes.* SOLEC specifically seeks to provide information and interpretations that are useful to those who make decisions or who influence environmental management practices, whether they are in government, industry, environmental groups or private practice.

- *To inform local decision-makers of Great Lakes environmental issues.* This objective emphasizes the importance of participation by local government and organizations.

- *To provide a forum for communication and networking amongst all the Great Lakes stakeholders.* Great Lakes stakeholders include representatives from federal governments, state and provincial governments, local governments, First Nations and native American Tribes, non-government environmental organizations, industry, academia, and private citizens.

SOLEC has provided an opportunity to look at the "big picture", by starting to integrate science issues. Air, land, water, biota, economics, and human health have been examined in a broad context, with linkages between and amongst these issues being drawn. SOLEC provides information on the state of the Lakes and the stresses on the Lakes to decision-makers in the basin. There is no other forum for this type of scientific debate.

The first SOLEC, 1994, provided a basic assessment of the state of the Great Lakes. This was an overview of the Great Lakes ecosystem, including human health and socio-economics. In 1996, SOLEC evaluated the nearshore environment and some land use issues, introducing the concept of Biodiversity Investment Areas. Both SOLECs assessed the health of the system using only ad hoc indicators and expert opinion.

In 1996, the Parties agreed that a basin-wide, systematic framework using science-based indicators was essential for reporting on ecosystem health. The Parties took this as a challenge for SOLEC 98.

At SOLEC 98, the Parties advanced the development of easily understood indicators which objectively represented the condition of the Great Lakes basin ecosystem, the stresses on the ecosystem, and the human responses to those stresses. These indicators would measure both the health of the system, and progress toward remedying existing problems. A suite of 80 ecosystem health indicators was presented for discussion, with the intention that this suite form the basis of reporting on the state of the Great Lakes. The complete suite and details on the process of indicator selection is in the ***Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 4.***

This present report on the State of the Great Lakes is the first report which applies the accepted suite of indicators, starting with 33 indicator assessments. The report is not comprehensive in terms of all 80 indicators. Some of these indicators will require agencies to collect additional data. Others need analysis and synthesis of data from non-traditional sources, such as municipalities, private sector and volunteer organizations. Some indicators need further development through research before they can be used for routine reporting.

This report also presents the condition of each of the Great Lakes and connecting channels as a whole. A general assessment has been made for Lakes Superior, Huron and Erie, and for the St. Clair - Detroit River corridor. The status of the fishery is presented for Lakes Michigan and Ontario, and the issue of biodiversity and non-native species are explored for the St. Lawrence River.

Another major thrust for SOLEC has been the development of the Biodiversity Investment Area (BIA) concept. This concept was first proposed in 1996 in the Nearshore Terrestrial paper for SOLEC 96, and subsequently included in the 1997 State of the Great Lakes report. In this present document, we provide a status report on the integration of nearshore terrestrial, coastal wetland and aquatic BIAs. The full text of the BIA report can be found on the SOLEC website.

# Section 2
# Lakes Assessment

## St. Lawrence River

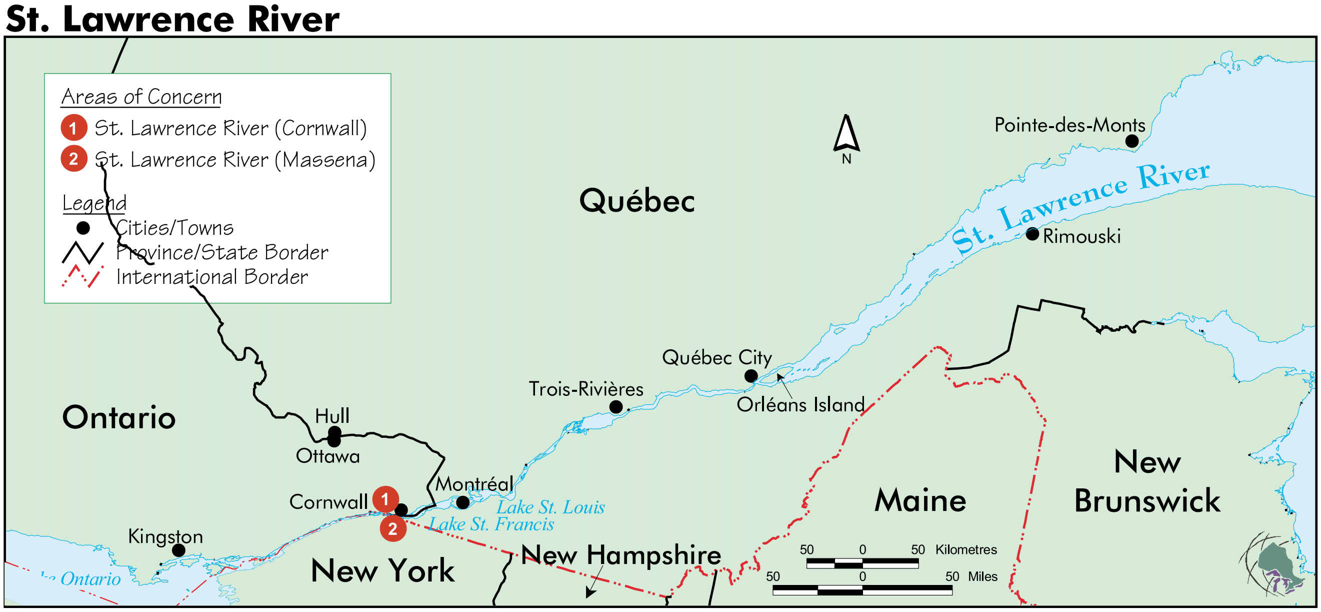
### State of Biodiversity and Aquatic Non-Native Species

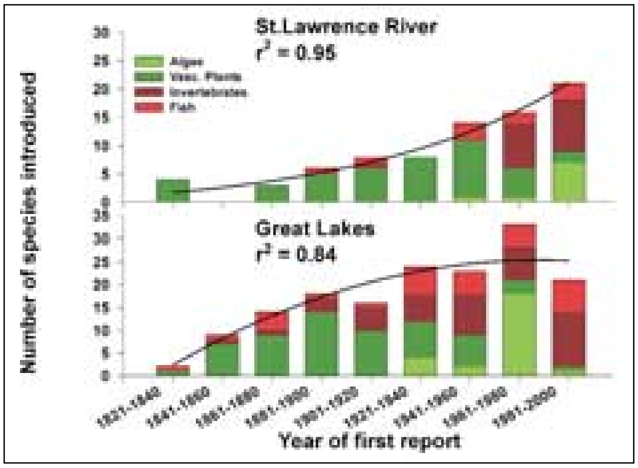
*The status of biodiversity in the St. Lawrence River is* ***mixed-deteriorating*** *because of continued habitat loss and the introduction of aquatic non-native species.*

The recently released Biodiversity Portrait of the St. Lawrence River (http://www.qc.ec.gc.ca/fauna/biodiver/) has emphasized the loss of wetlands as one of the major factors affecting the integrity of the River ecosystem. The amplitude of annual water level fluctuations has decreased following the opening of the St. Lawrence Seaway, reducing the diversity of wetland flora and affecting fish populations that depend upon flooded wetlands for spawning. Approximately 50% of the St. Lawrence River shoreline has been modified by agriculture and urbanization. Erosion is a concern along 25% of the shoreline. The result is the loss of both terrestrial and aquatic natural habitats. For example, more than 1,500 hectares of island habitats have been lost since 1950. Still more important losses are predicted if River flows decline because of climate change.

Although habitat loss is having an impact on the St. Lawrence freshwater fish community, aquatic non-native species introductions to the River may be a more serious threat. To aid in developing a conservation strategy for the St. Lawrence River ecosystem, aquatic non-native species introductions are now being studied by Environment Canada. A list of introduced aquatic species is being compiled, the transfer of species between the Great Lakes and the River is being evaluated, and the spatial distribution and temporal trend of introduced species is being assessed using available literature and databases.

**St. Lawrence River**






Trends in species introductions since 1820.
Source: St. Lawrence Centre-Environment Canada

Recent information indicates a continuing upward trend in aquatic non-native species introductions to the St. Lawrence River with an average rate of one species per year. Approximately 50% of the aquatic non-native species introduced to the Great Lakes have been reported in the St. Lawrence River. Upstream transfer of species from the River to the Lakes is also a source of species introductions to the Great Lakes. However, the problem of non-native species introductions to the St. Lawrence River is due primarily to downstream transfer from the Great Lakes. The percent of species transferred has increased with time, and is expected to remain high over the next decade considering that close to half the species introduced in the Great Lakes have not yet reached the River.

The conclusions regarding biodiversity and aquatic non-native species in the St. Lawrence River are that:

- Despite important habitat losses and modifications, further losses are anticipated as a result of climatic changes that will certainly affect the biodiversity of the River;
- There are insufficient data to assess or predict the potential impact of non-native species in the river;
- The information on aquatic non-native species presence and their distribution need to be validated;
- Guidelines for ship ballast exchange should be rigorously applied and compliance should be enforced for the St. Lawrence River; and
- Overall, the biodiversity of the St. Lawrence River is under considerable stress.

**St. Lawrence River Statistics**

| | |
|---|---|
| **Elevation** | Kingston<br>246 ft. 75 m<br>Lake St. Francis<br>151 ft. 46 m<br>Lake St. Louis<br>66 ft. 20 m<br>Montreal<br>18 ft. 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<br>305 mi. 490 km<br>South Shore<br>280 mi. 450 km |
| **Transient Time** | |
| hours (minimum) | 100 [e] |
| **Outlet** | Gulf of St. Lawrence |

[a] Length of 964 km is from Kingston to Pointe-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 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

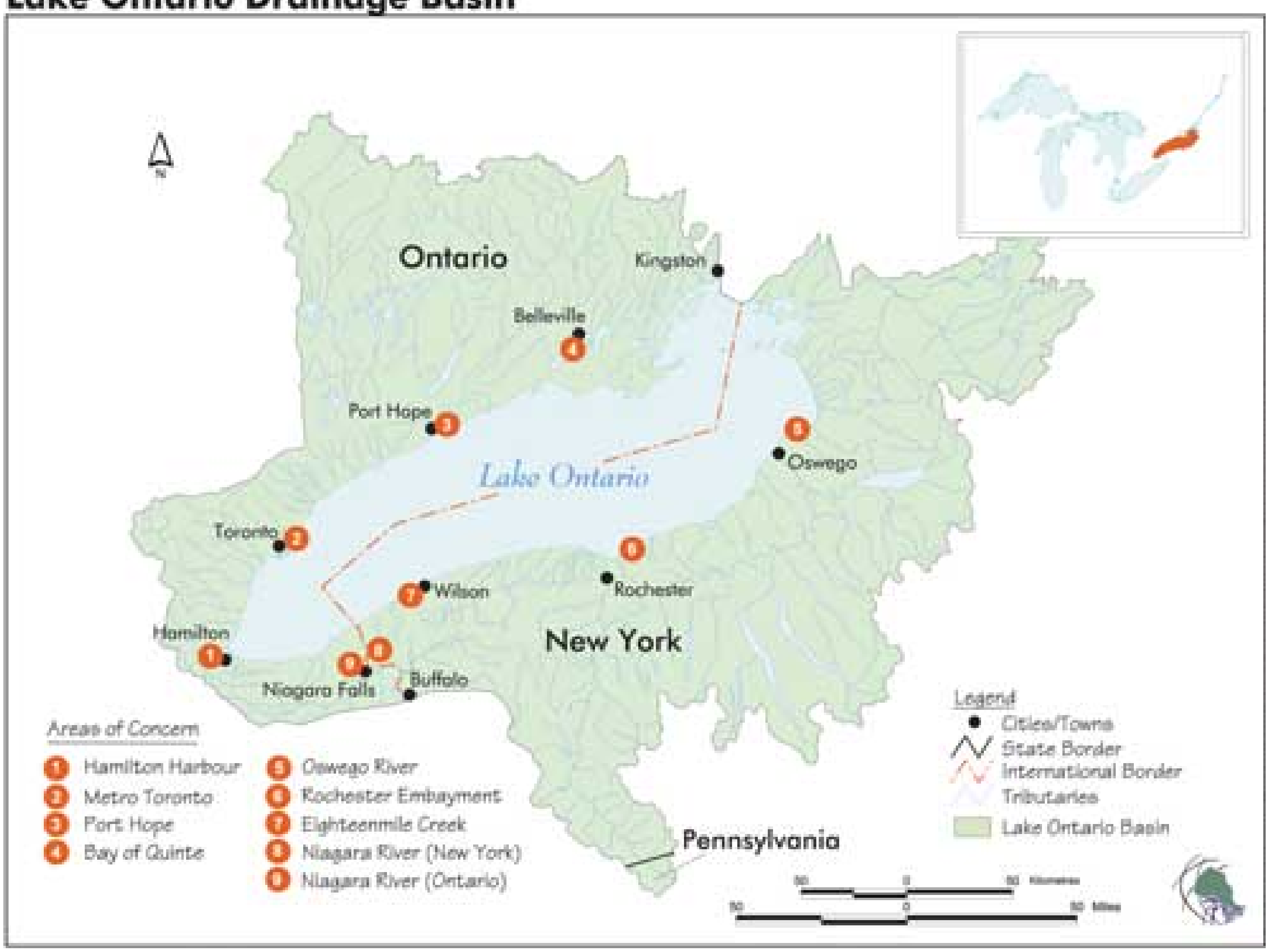
## State of Lake Trout

*The status of Lake Ontario lake trout is **mixed** because of recent increases in wild young-of-the-year juveniles, but also because of decreased survival of stocked lake trout, no increase in wild fish abundance, a diet consisting mostly of alewives, and early mortality syndrome.*

Lake trout is native to all five lakes. It is a top predator that requires oligotrophic (low nutrient levels) conditions and clean spawning substrate. It has a long life span, is genetically diverse, and integrates many ecosystem components. The dominant dietary item is the alewife. The paradox is that the alewives prey on lake trout fry and are probably linked with Early Mortality Syndrome. The Syndrome is caused by thiamine (vitamin B1) deficiency. The management dilemma is that the prey species that supports an economically valuable fishery inhibits the survival of lake trout and other native species.

Native lake trout have been extirpated (eliminated) from all of the Great Lakes except Superior. Four stressors contributed to the extirpation: over-fishing as early as the nineteenth century; habitat loss from development and agriculture; non-native invasive species such as the sea lamprey; and, contamination of fish by dioxin-like chemicals beginning in the 1930s and peaking in the late 1960s. Contamination levels may have been high enough for 100% mortality of

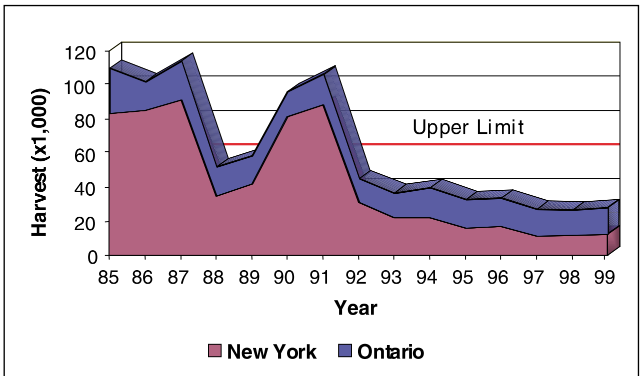
**Lake Ontario Drainage Basin**



young fish (fry) from 1945 to 1975. After 1991, levels were below the threshold for adverse effects.

Fishery management agencies for Lake Ontario have established a goal of rehabilitating the lake trout population such that, "The adult spawning stock(s) encompasses several year classes, sustains itself at a relatively stable level by natural reproduction, and produces a usable annual surplus (harvest)."

On the positive side, natural reproduction of lake trout has occurred in Lake Ontario since 1985. The proportion of older fish has increased since 1994, while the average age of mature females has been increasing. Fishing mortality remains low. The distribution of naturally produced fish has been widespread throughout the lake, and recent information from the U.S. side of Lake Ontario indicates that numbers of wild lake trout young-of-the-year increased in the spring of 2001. The sea lamprey control program has been effective and lamprey are under control.




Lake trout sport harvest, Lake Ontario.

Source: New York State Department of Environmental Conservation, and Ontario Ministry of Natural Resources

On the negative side, there is decreased survival of stocked lake trout, there has been no increase in total numbers of wild fish, lake trout diet consists mostly of alewives, and early mortality syndrome is still a problem.

The keys to the future success of lake trout rehabilitation in Lake Ontario include improved survival of stocked lake trout; diversification of diet; continued effective sea lamprey control; habitat protection; restrictive angling regulations; and continued low contaminant levels.

Beyond lake trout rehabilitation work, the Lakewide Management Plan for Lake Ontario proposes three categories of ecosystem indicators: 1) critical pollutant indicators including open water, young-of-the-year fish, herring gull eggs, and lake trout; 2) lower food web biological indicators including nutrients, zooplankton, and preyfish; and, 3) upper food web biological indicators including herring gull, lake trout, mink and otter, and bald eagle.

### Lake Ontario Statistics

| | |
|---|---|
| **Elevation**[a] | |
| feet | 243 |
| metres | 74 |
| **Length** | |
| miles | 193 |
| kilometers | 311 |
| **Breadth** | |
| miles | 53 |
| kilometers | 85 |
| **Average Depth**[a] | |
| feet | 283 |
| metres | 86 |
| **Maximum Depth**[a] | |
| feet | 802 |
| metres | 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 |
| kilometres | 1,146 |
| **Retention Time** | |
| years | 6 |
| **Population:** | |
| **USA (1990)†** | 2,704,284 |
| **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
[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

## A Changing Ecosystem

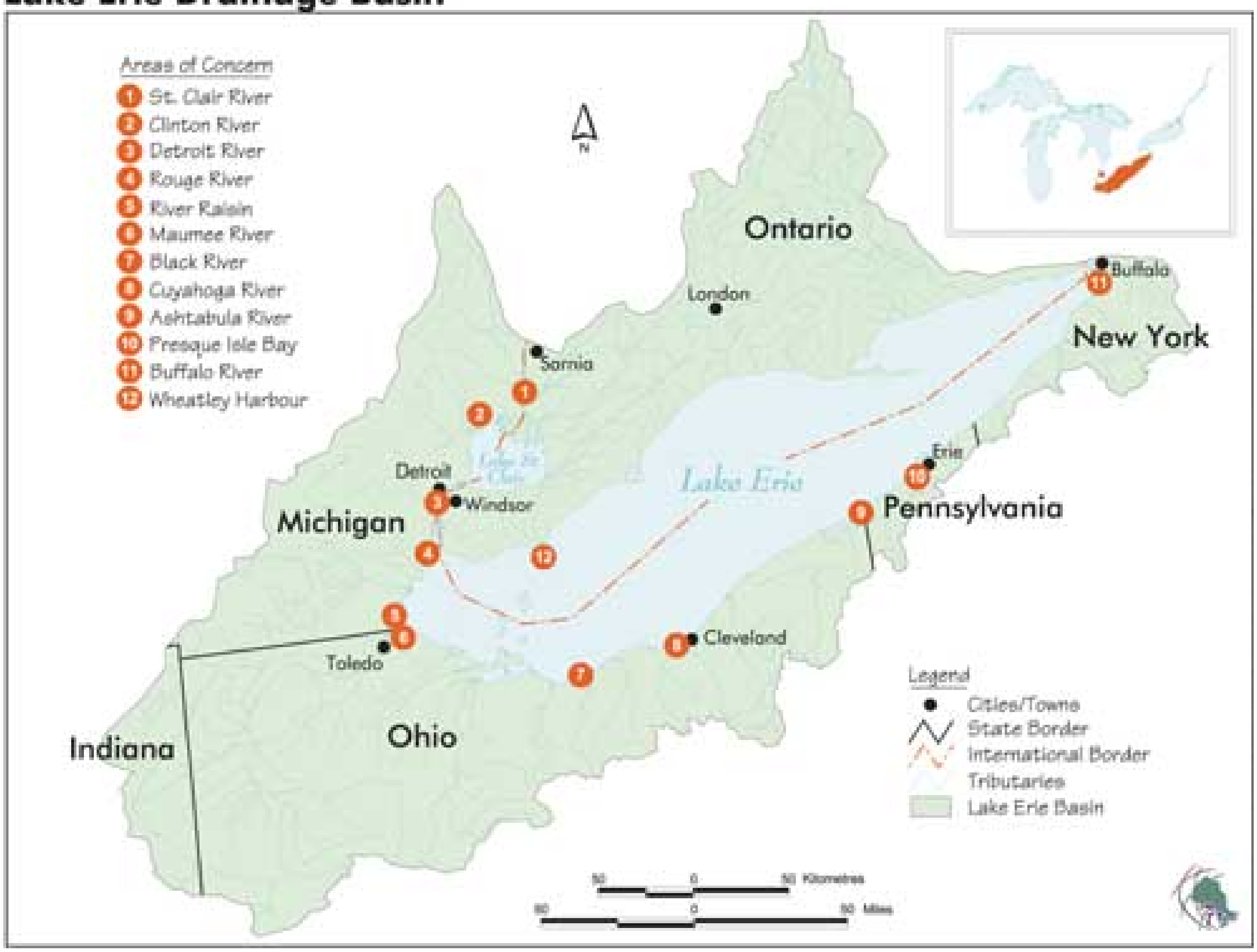
*The status of Lake Erie is **mixed** to **mixed-deteriorating** because of continued aquatic non-native species impacts, habitat loss or alteration, and contamination by toxic chemicals.*

One-third of the human population of the Great Lakes basin lives in the intensively urbanized and agricultural Lake Erie watershed. In addition to providing drinking water for 11 million people, Lake Erie is used for many purposes, including industrial, recreational, municipal and agricultural. Issues and concerns affecting the health of the Lake Erie ecosystem include continued contamination of fish and wildlife by toxic chemicals, increasing nutrient levels, an influx of aquatic non-native species, and continued habitat loss.

### Contaminants

The chemicals of concern include toxic substances (PCBs, chlordane, DDT and metabolites, dioxins, dieldrin, PAHs, agricultural pesticides, endocrine disruptors), heavy metals (lead, mercury), and nutrients (phosphorus, nitrates). For example, although PCBs in Lake Erie sediments decreased from 1971 to 1995, there are still high concentrations in the Western Basin despite contaminant reductions.

**Lake Erie Drainage Basin**



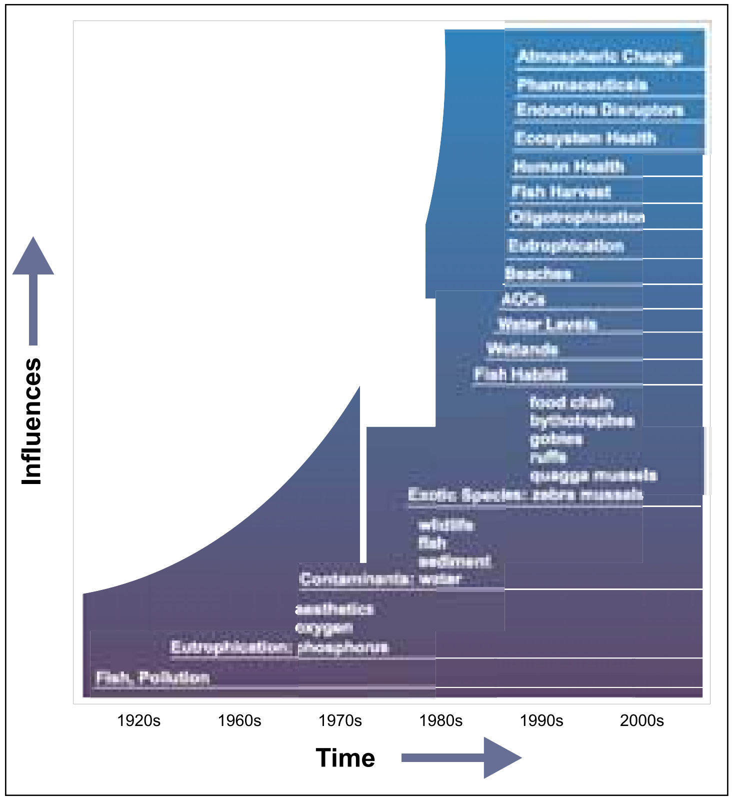
| Lake Erie Statistics | |
|---|---|
| **Elevation**[a] | |
| feet | 569 |
| metres | 173 |
| **Length** | |
| miles | 241 |
| kilometers | 388 |
| **Breadth** | |
| miles | 57 |
| kilometers | 92 |
| **Average Depth**[a] | |
| feet | 62 |
| metres | 12 |
| **Maximum Depth**[a] | |
| feet | 210 |
| metres | 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 |
| kilometres | 1,402 |
| **Retention Time** | |
| years | 2.6 |
| **Population:** | |
| **USA (1990)†** | 10,017,530 |
| **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
[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

### Nutrients

Although significant reductions in the annual loadings of phosphorus to Lake Erie has been achieved since the early 1970s, concentrations of phosphorus in the Western and Central Basins still regularly exceed the target levels derived from the Great Lakes Water Quality Agreement. In addition, the concentration of nitrates in the Eastern and Western Basins has increased since the early 1980s, possibly affecting amphibians and reptiles.




Influences on the Lake Erie ecosystem through time.
Source: Environment Canada

### Non-native Species

Aquatic non-native species such as zebra mussels, the round goby, purple loosestrife, and the fishhook water flea (*Cercopagis*) are continuing to disrupt the food web. Zebra mussel grazing in particular appears to be altering community structure. The abundance of phytoplankton in the Eastern Basin is less than predicted from phosphorus concentrations in the water, and *Microcystis* (a type of blue green alga) blooms have appeared in the Western Basin. Populations of large, cold water species of zooplankton have been reduced, and zebra mussel larvae and the spiny waterflea (*Bythotrephes*) are replacing native zooplankton populations.

### Fisheries

Walleye and yellow perch populations are declining, while lake whitefish harvest is increasing.

### Habitat

Lake Erie basin natural habitats are continuing to degrade, including wetlands, forests, sand beaches, dunes and barrens, lakeplain prairies, as well as tributaries and the open lake. Emerging issues such as climate change will add to existing problems as will continued human population growth.

The ability to monitor and track changes in the Lake Erie ecosystem has been diminished because ecosystem changes are occurring rapidly, and because resources for monitoring are declining. Research is needed to understand changes in the ecosystem.

## St. Clair River - Lake St. Clair - Detroit River Corridor

*The status of the St. Clair River - Lake St. Clair - Detroit River Corridor is **mixed** because of fish consumption advisories, historical and current wetland losses, a degraded benthos, contaminated sediments, exceedances in water quality standards, beach closures, and problems with drinking water; but contaminants are generally below problem levels and there have been incremental gains in habitat protection and restoration.*

The corridor consists of the St. Clair and Detroit Rivers, and Lake St. Clair. The major population centres are Port Huron, Michigan; Sarnia, Ontario; Detroit, Michigan; and Windsor, Ontario. The population centres are also industrial centres. The Michigan side of the corridor is largely populated, with wetland areas remaining on the north side of Lake St. Clair. The Ontario side is agricultural. Walpole Island, which is First Nations territory, has superb tallgrass prairie, wetland, and oak savanna habitats.

**The St. Clair - Detroit Corridor**


Lake St. Clair was surrounded primarily by wetlands prior to European settlement, and although these wetlands are considerably smaller today, Lake St. Clair is still habitat for a diverse fishery. Recreational boating and fishing are of great economic importance in the region. There are currently about 200 marinas and 150,000 boats in Michigan alone, with an annual value to the economy of approximately $260 million. More than 1.5 million fish are taken from Lake St. Clair annually, accounting for nearly half of the entire Great Lakes sport fishing industry.

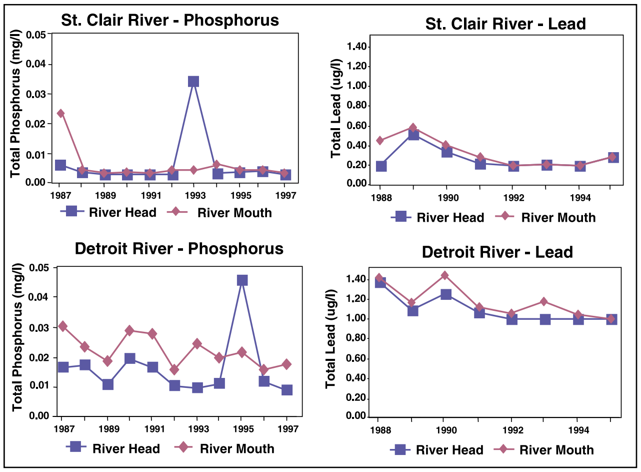
The issues or problems that indicate the health of the Corridor is degraded are: fish consumption advisories, historical and current wetland losses, a degraded benthos, contaminated sediments, exceedances of water quality standards and guidelines, beach closures, and problems with drinking water.

In the St. Clair River, lead and chloride levels have decreased. Phosphorus levels increased in the mid-1990s but are now leveling off. Levels of copper are constant, but zinc levels have been rising.

In Lake St. Clair, chloride levels are constant. Mercury levels in the edible portion of walleye have decreased significantly, PCB levels increased in 2000 after a steady decline. HCB and OCS levels in channel catfish have declined.

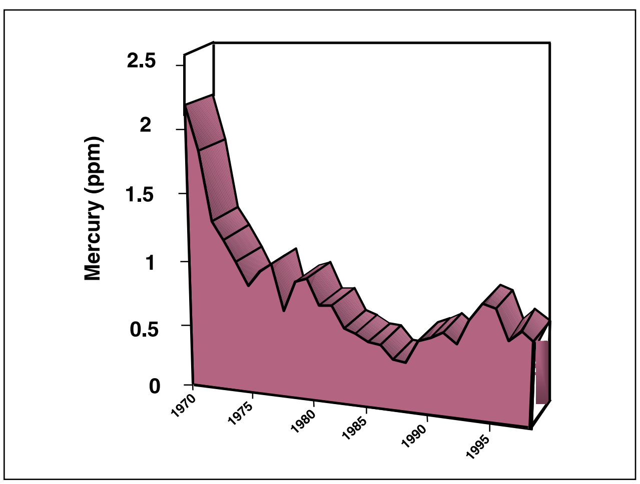
In the Detroit River, lead has decreased, while chloride has increased slightly at the head of the river. Levels of copper and zinc are constant.

Historic coastal wetland losses in the Corridor were severe. However, since the early 1980s, the total area of protected and restored wetlands has increased. In the last two




Comparison of phosphorus and lead levels at St. Clair and Detroit Rivers.

Source: Ontario Ministry of Environment and Environment Canada




Mercury levels in Lake St. Clair walleye.

Source: Environment Canada

decades, more than 500 hectares in the St. Clair River, 3000 hectares in Lake St. Clair, and 500 hectares in the Detroit River have been protected or restored.

Spills to the St. Clair and Detroit Rivers have decreased considerably since 1986. Water quality has shown a marked improvement.

Loss of fish and wildlife habitat is a primary and consistent concern throughout the Corridor. Current activities to mitigate habitat loss are:

- Critical habitat acquisition;
- Shoreline enhancement;
- Development of a biodiversity conservation strategy and atlas;
- Identification of candidate sites for protection and rehabilitation; and
- Protection of designated wetlands.

In conclusion, the Corridor is important ecologically and commercially. Current needs are:

- Effective source controls for current contamination and better management of historical contamination;
- Focus on habitat protection and restoration with a view toward incremental gains; and
- Ongoing monitoring to ensure continuous improvement.

**Lake St. Clair Statistics**

| | |
|---|---|
| **Elevation** | |
| feet | 569 |
| metres | 173 |
| **Length** | |
| miles | 26 |
| kilometers | 42 |
| **Mean Breadth** | |
| miles | 24 |
| kilometres | 39 |
| **Mean Depth** | |
| feet | 11 |
| metres | 3.4 |
| **Mean Annual Discharge** | |
| $ft.^3/s$ | 183,000 [a] |
| $m^3/s$ | 5,182 [a] |
| **Maximum Depth (natural)** | |
| feet | 21 |
| metres | 6.5 |
| **Watershed Area** | |
| sq. mi. | 460 |
| $km^2$ | 1,191 |
| **Land Drainage Area** | |
| sq. mi. | 6,100 [b] |
| $km^2$ | 5,799 [b] |
| **Water Surface Area** | |
| sq. mi. | 400 [c] |
| $km^2$ | 1,036 [c] |
| **Shoreline Length** | |
| miles | 62 |
| kilometres | 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: Its Current State and Future Prospects, Lake St. Clair Network, United States Geological Survey

## The Lake in the Middle

*The status of Lake Huron is **mixed** because, despite gains in terms of point source controls and progress in Areas of Concern, there are still stresses attributed to large atmospheric inputs of contaminants; hardened shorelines; and continued threats from non-native species.*

Lake Huron is often called "the lake in the middle" due to its position in the Great Lakes and the view that the level of pollution is somewhere between "pristine" Lake Superior and Lake Ontario. In spite of its "middle" status, Lake Huron is interesting and unique. Lake Huron has over 30,000 islands, more than any other lake in the world. The largest, Manitoulin, is the largest island in a freshwater lake. If the shorelines of the islands are included, Lake Huron has the longest lakeshore of any lake in the world as well. More than 2.5 million people live in the basin, mostly in the southern portion. Historical pollution discharges, particularly in Sarnia, Ontario and Saginaw Bay, Michigan, have caused serious problems in a number of areas in the basin, including the designation of five Areas of Concern. The five Areas are the St. Marys River, Spanish River, Saginaw River and Bay, Severn Sound, and the St. Clair River. Current activities, including industry and seasonal land use development, are putting increasing pressures on wildlife habitats and unique ecosystems.

Critical pollutants have been identified and include PCBs, chlordane, dioxins, mercury,

**Lake Huron Drainage Basin**

**Lake Huron Statistics**

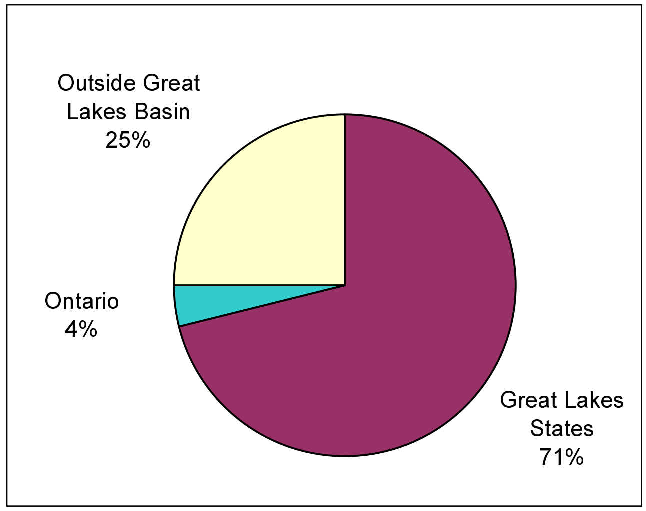
| | |
|---|---|
| **Elevation**[a] | |
| feet | 577 |
| metres | 176 |
| **Length** | |
| miles | 206 |
| kilometers | 332 |
| **Breadth** | |
| miles | 183 |
| kilometers | 245 |
| **Average Depth**[a] | |
| feet | 195 |
| metres | 59 |
| **Maximum Depth**[a] | |
| feet | 750 |
| metres | 229 |
| **Volume**[a] | |
| 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 |
| kilometres | 6,157 |
| **Retention Time** | |
| years | 22 |
| **Population:** | |
| **USA (1990)†** | 1,502,687 |
| **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. Marys 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

sediment/suspended solids, and DDT. Concentrations of PCBs in whole lake trout have declined significantly since 1978, but are still above the protection values for fish-eating birds and mammals. There has been no significant decline in PCBs or mercury since the mid-1980s. Continuing sources may include historical discharges and air deposition. The rate of decrease for contaminant trends in fish eating birds has slowed. Most bird populations have become re-established, but some reproductive problems persist. Bald eagle populations continue to grow, with interior breeding areas having greater productivity than nearshore ones. Loadings from water sources are the lowest of the Great Lakes, but air sources are the highest. About 80%-90% of dioxins are from atmospheric sources. Contaminated sediments in the Areas of Concern and out-of-basin atmospheric deposition must be addressed to deal with critical pollutant issues.

Nearshore terrestrial ecosystems still sustain a great diversity of wildlife. They sustain important habitats as food sources for fish and wildlife. Saginaw Bay continues to provide essential habitat, but a continued loss of wetlands is a serious threat. Critical stresses include degradation and loss of historical tributary and nearshore habitats, the introduction of non-native species, over-fishing, and fish and wildlife reproductive failure.




Sources of atmospheric deposition of dioxin to Lake Huron, 1999.

Source: Great Lakes Trends: Into the New Millennium, Office of the Great Lakes, Michigan Department of Environmental Quality

The Lake Huron fisheries goals are:

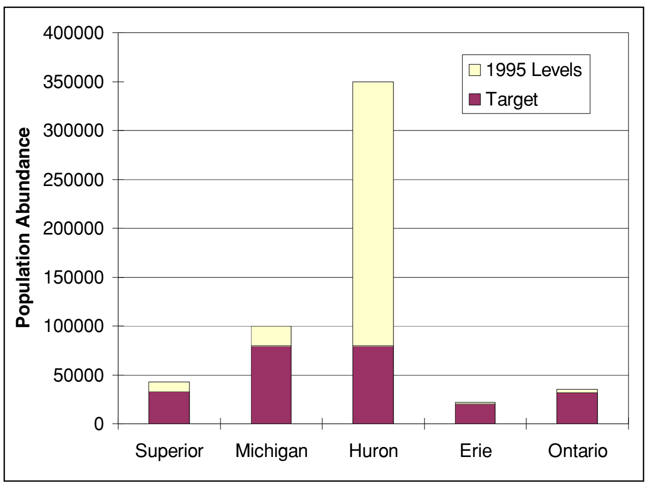
- to protect and enhance existing habitats and rehabilitate degraded habitats;
- to achieve no net loss of the productive capacity of habitats;
- to restore damaged habitats; and
- to support the reduction of contaminants.

However, there are several fishery concerns such as the dependence on hatchery production, the impact of non-native species on fish communities, and the insufficient rate of lake trout reproduction, as well as those concerns discussed in the following paragraphs.

One fishery concern is that historically, tributaries were important sources of cool, high quality water serving as spawning and nursery habitat. The construction of dams has excluded fish from many tributaries. This is a deterrent to achieving balanced fish communities because tributaries are now inadequate habitat for all life cycle stages. Dams now fragment many streams where historical spawning occurred.

A second fishery concern is nearshore habitat. Many nearshore areas have been altered with shoreline protection structures. In many areas, the band of transition vegetation has disappeared. The cumulative impact of these structures is significant and increasing in regard to the fishery.

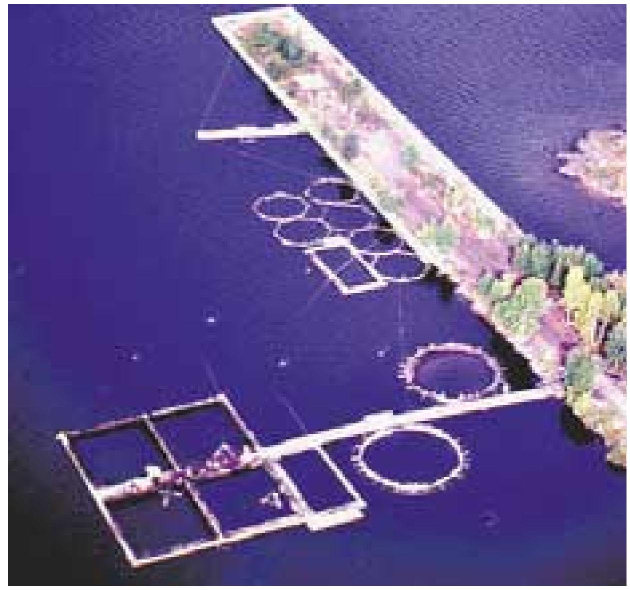
A third concern is the loss of coastal wetlands. Most current coastal wetland losses have been around small urban centres on the lakeshore. Losses are due to agriculture, cottage development, road construction, dredging, and channelization.




Sea lamprey populations and targets.
Source: Great Lakes Fishery Commission

A fourth fishery concern is the significant stress to aquatic communities caused by non-native species. Species that are having a great impact are the sea lamprey, zebra mussel, ruffe, round goby, and purple loosestrife. The sea lamprey problem is associated with production in the St. Marys River and is the most severe impediment to a healthy fish community. Cost effective sea lamprey control on the river may be within reach. The sea lamprey population is expected to be reduced by 85% by 2010.

Finally, aquaculture is a growing fishery concern. Fish farms now account for over 60% of rainbow trout production in the Ontario waters of Lake Huron.



Aquaculture pens near Parry Sound, Georgian Bay.
Source: Ontario Ministry of Natural Resources

The following actions are still needed to improve the Lake Huron ecosystem:

- Control atmospheric inputs of persistent toxic substances;
- Initiate an aquatic nuisance species control program beyond the sea lamprey control program;
- Continue progress in Areas of Concern;
- Implement watershed management plans;
- Fully fund the lamprey control program;
- Encourage local protection and restoration efforts;
- Research lower trophic levels; and
- Control pathogen sources (Saginaw Bay and southeast Lake Huron).

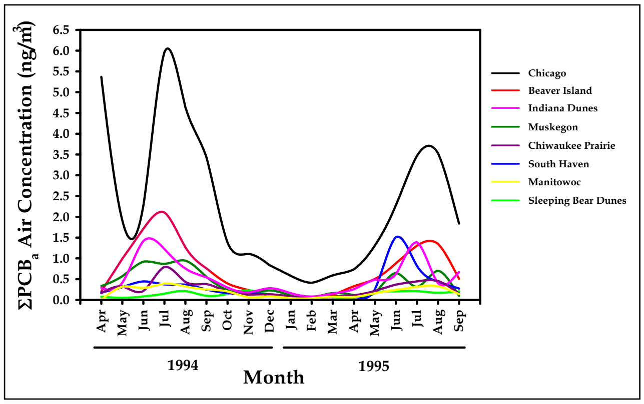
## State of the Fishery

*The status of Lake Michigan is* ***mixed*** *because of continued impairments and only slight improvement towards the goals established by the Lakewide Management Plan. The status of progress toward achieving Lake Michigan fish community objectives is as follows: fish population structures–mixed/improving; restoration or protection of fish habitat–mixed/deteriorating; prevention or control of aquatic nuisance species–mixed.*

Lake Michigan is an outstanding natural resource of global significance, but it is under stress and in need of special attention. It is the second largest lake by volume and has the world's largest collection of freshwater sand dunes. It has approximately 40% of all the Great Lakes coastal wetlands and more than 26% of the prime waterfowl. It also has ten Areas of Concern in various stages of cleanup.

The sources of continuing contamination to the lake include atmospheric deposition, tributaries, and historic sediment deposition. The southern-most end of the lake has the highest concentrations of PCBs, with the PCB loadings for the lake primarily from the atmosphere at 1536 kilograms (3386 pounds) per year. Atmospheric mercury and atrazine loadings, in large part deposited by rain and snow, are 729 and 1694 kilograms per year respectively (1607 and 3735

**Lake Michigan Drainage Basin**




Atmospheric concentration of PCB over Lake Michigan.

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

pounds respectively). PCB loadings (1994 data) from major monitored tributaries are greatest from the Fox River, Grand Calumet Harbor, and Kalamazoo River. According to 1995 data, atrazine loadings are greatest from the Fox, St. Joseph, Pere Marquette, and Kalamazoo Rivers. Mercury loadings (1995 data) are greatest from the Fox, Grand, Kalamazoo, and St. Joseph Rivers.

The fish community goal for Lake Michigan is to restore and maintain the biological integrity of the fish community so that production of desirable fish is sustainable and ecologically efficient. For preyfish species, the objective is to maintain a diversity of preyfish species at population levels matched to primary production and to predator demands. Expectations are for a lakewide preyfish biomass of 0.5 to 0.8 billion kilograms (1.2 to 1.7 billion pounds). However the abundance of benthos (bottom organisms) at 40 sites in Lake Michigan's southern basin has shown a decline in bottom life, likely linked to the introduction of zebra mussels. The dominant species, *Diporeia*, is eaten by a variety of Great Lakes fish and is an important component of the Lake Michigan food web. Another component of the forage base, bloater chub, alewife, and rainbow smelt has also declined since the early 1990s.

For salmon and lake trout, the objective is to establish a diverse harvest of 2.7 to 6.8 million kilograms (6 to 15 million pounds) of which 20-25% is lake trout. Another objective is to establish self-sustaining lake trout populations. Lakewide trout and salmon harvests have dropped since the mid-1980s.

For bottom feeders, the objective is to maintain self-sustaining stocks of lake whitefish, round whitefish, sturgeon, suckers, and burbot. The expected annual yield of lake whitefish alone should be 1.8 - 2.7 million kilograms (4 to 6 million pounds), but for 1999, the lakewide harvest of all these fish was about 3.2 million kilograms (7 million pounds).

The goal of inshore fish stocks is to maintain self-sustaining stocks of yellow perch, walleye, smallmouth bass, pike, catfish, and panfish. Expected annual yields should be 0.9 to 1.8 million kilograms (2 to 4 million pounds) for yellow perch and 0.1 to 0.2 million kilograms (0.2 to 0.4 million pounds) for walleye. In 1999, the lakewide yellow perch harvest was about 272,000 kilograms (600,000 pounds), a steady decline from the mid to late 1980s. The lakewide walleye harvest was just under 68,000 kilograms (150,000 pounds), or at about the same level since 1985.

Other fish community objectives include protecting and sustaining a diverse community of native species, including other species not specifically mentioned earlier such as gars and bowfin. These

**Lake Michigan Statistics**

| | |
|---|---|
| **Elevation**[a] | |
| feet | 577 |
| metres | 176 |
| **Length** | |
| miles | 307 |
| kilometers | 494 |
| **Breadth** | |
| miles | 118 |
| kilometers | 190 |
| **Average Depth**[a] | |
| feet | 279 |
| metres | 85 |
| **Maximum Depth**[a] | |
| feet | 925 |
| metres | 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 |
| kilometres | 2,633 |
| **Retention Time** | |
| years | 99 |
| **Population: USA (1990)†** | 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

species contribute to the biological integrity of the fish community and should be recognized and protected for their ecological significance and cultural and economic values. Another fish community objective is to suppress the sea lamprey to allow the achievement of other fish community objectives.

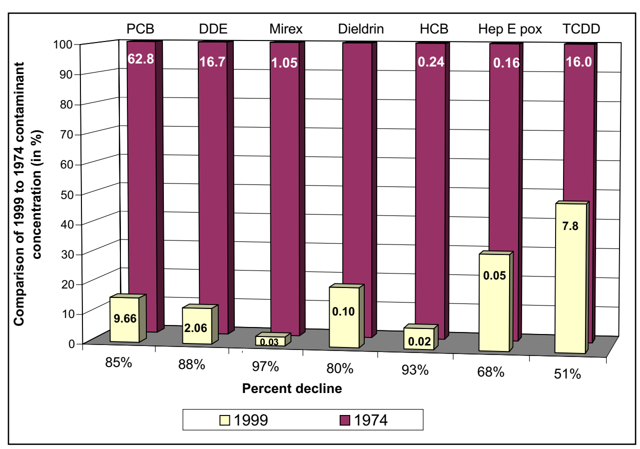
In conclusion, progress toward achieving fish community objectives is mixed/improving for fish population structures; mixed/deteriorating for the restoration and protection of fish habitat; and mixed for the prevention/control of aquatic nuisance species. To protect and enhance fish habitat and rehabilitate degraded habitats, it will be necessary to achieve a "no net loss" of the productive capacity of habitat supporting Lake Michigan's fish communities. High priority should be given to the restoration and enhancement of historic riverine spawning and nursery areas for anadromous species.

## State of the Ecosystem

*The status of the Lake Superior basin ecosystem is **mixed** because of: poor offshore chub populations; mixed (some gains and some losses) in terms of continued fish consumption advisories, the status of herring gull populations, critical pollutant reductions, atmospheric deposition, human population change, quantity of water consumed; mixed/improving for lake trout nearshore, all habitats for lake herring, sea lamprey abundance; and good for lake trout offshore habitat and lake whitefish nearshore.*

Lake Superior's aquatic communities are closest to what the communities of the Great Lakes must have been like prior to European settlement. The status of these aquatic communities is measured by two indicators: fish abundance, including lake trout, chubs, lake herring, and whitefish, and sea lamprey abundance.

The trend in catch for lean and Siscowet lake trout in commercial fisheries from 1950 to 1998 has not changed for lean trout and is upward with fluctuations for Siscowet trout. Catch per unit effort for lake herring is declining while the chub fishery is almost non-existent. Lake whitefish catch per unit effort for both gill net and trap net has risen over the last decades. Sea lamprey has declined since the 1950s with a slight rise in 1999.




Contaminants in herring gull eggs, Lake Superior, 1974 vs. 1999 data.

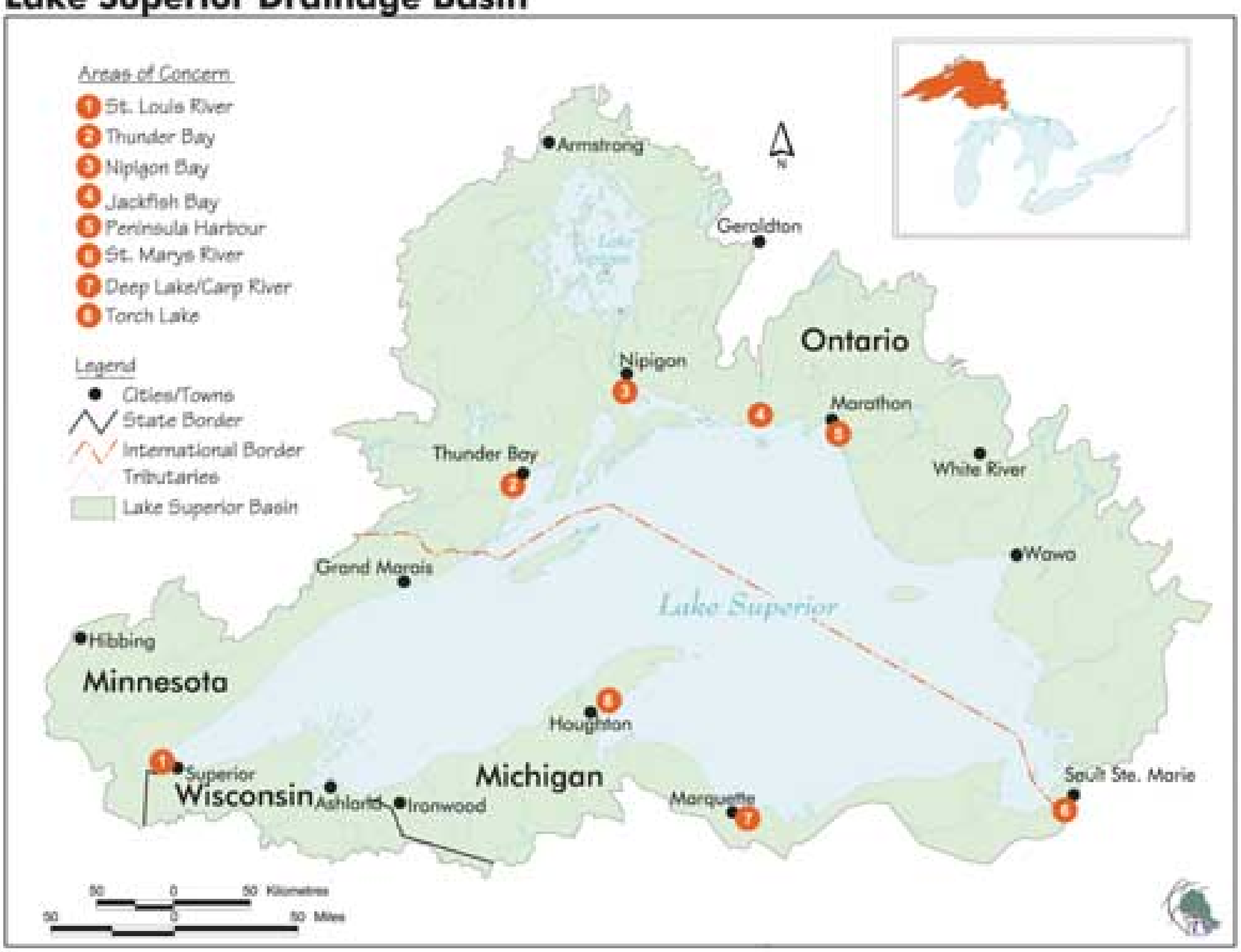
Source: Environment Canada

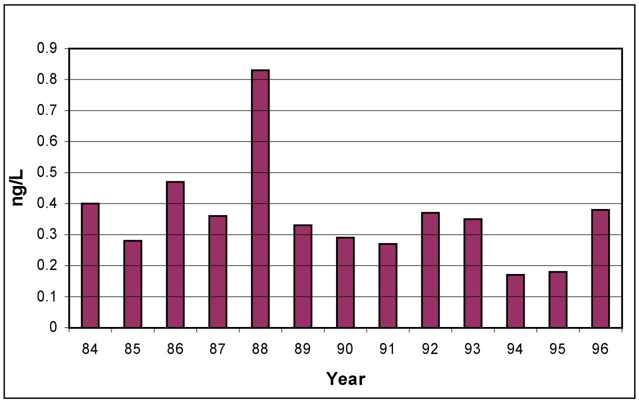
Wildlife community indicators are forest breeding birds, with trends unique to the local environment, and colonial waterbirds, where herring gulls are indicators of regional contaminant levels. Herring gull contaminants–PCBs, DDE, mirex, dieldrin, HCB, heptachlor-epoxide, and TCDD–have declined from 51% to 97% since 1974. Herring gull abundance, measured in number of breeding pairs and number of colonies, has nearly doubled in Canada between 1976 and 1999. In the United States, numbers have increased only slightly, from 7,106 pairs to 7,715 and from 90 colonies to 134.

Progress toward the management goal of zero discharge of emissions of nine critical pollutants is mixed. The mercury goal for 2000 has been met. But meeting the 2010 milestones will require strategies relating to fuel combustion and mining. Mercury emissions from sources in the Lake Superior basin have decreased to about 1,000 kilograms per year. Open lake concentrations of most toxic chemicals are lower than the most sensitive guidelines, except for dieldrin at 0.114 ng/L; PCBs at 0.0705 per ng/L; and toxaphene at 0.9 and 0.7 ng/L. PCBs in Chinook salmon (0.3 ppm) are still well above the unlimited consumption level of 0.05 ppm.

One Lakewide Management Plan objective is the virtual elimination of atmospheric emissions of toxic chemicals of human origin from the lake. Atmospheric deposition is the dominant pathway for critical pollutants. Atmospheric loadings will continue for an unknown length of time.

**Lake Superior Drainage Basin**






Dieldrin trends in Lake Superior precipitation.
Source: Environment Canada

Indicators of how well humans are being sustained by the landscape are related to use of ecosystem resources, trends in human population density and municipal water use. Data from Ontario show a relatively stable population base and a stable per capita residential water use.

Lake Superior emerging issues are numerous and include: introduction of non-native species, airborne pollutants, human migration into the basin, habitat fragmentation, meeting zero-discharge milestones, exposure and effects of chemical mixtures, endocrine disrupting chemicals, mercury, new chemicals, and domestic use of burn barrels. The Lake Superior Binational Program's initial focus has been on the Zero Discharge Demonstration Program. In 1997, the Program broadened to incorporate six ecosystem themes in its charge. Active public participation was sought through the Binational Forum. Project implementation is underway during 2000 to 2002.

**Lake Superior Statistics**

| | |
|---|---|
| **Elevation**[a] | |
| feet | 600 |
| metres | 183 |
| **Length** | |
| miles | 350 |
| kilometers | 563 |
| **Breadth** | |
| miles | 160 |
| kilometers | 257 |
| **Average Depth**[a] | |
| feet | 483 |
| metres | 147 |
| **Maximum Depth**[a] | |
| feet | 1,332 |
| metres | 406 |
| **Volume**[a] | |
| cu. mi. | 2,900 |
| $km^3$ | 12,100 |
| **Water Area** | |
| sq. mi. | 31,700 |
| $km^2$ | 82,100 |
| **Land Drainage Area** | |
| sq. mi. | 49,300 |
| $km^2$ | 127,700 |
| **Total Area** | |
| sq. mi. | 81,000 |
| $km^2$ | 209,800 |
| **Shoreline Length**[b] | |
| miles | 2,729 |
| kilometres | 4,385 |
| **Retention Time** | |
| years | 191 |
| **Population:** | |
| **USA (1990)†** | 425,548 |
| **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

# Section 3
# State of the Great Lakes Based on Indicators

The status of the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem has been assessed and is considered mixed because:

- Surface waters are still amongst the best sources of drinking water in the world;
- Progress has been made both in cleaning up contaminants and in rehabilitating some fish and wildlife species;
- Invasive species continue as a significant threat to Great Lakes biological communities;
- Atmospheric deposition of contaminants from distant sources outside the basin confounds efforts to eliminate these substances;
- Urban sprawl threatens high quality natural areas, rare species, farmland and open space; and
- Development, drainage, and pollution are shrinking coastal wetlands.

These conclusions are based on assessments of 33 indicators made by the governments of Canada, United States, Provinces, States, Tribes, and First Nations, including local governments, industry, academia, and non-governmental organizations. The indicators are part of suite of 80 that have been determined to be necessary, sufficient and feasible in order to convey a picture of Great Lakes basin health. Several categories comprise the suite: **open and nearshore waters, coastal wetlands, nearshore terrestrial, land use, human health, societal,** and **unbounded** (those indicators that transcend the other categories - for example, Acid Rain or indicators of climate change).

The assessment is incomplete. Data for several indicators within this report are uneven (or not basin-wide) across jurisdictions. Of a total of 80 Great Lakes ecosystem indicators, 47 have yet to be reported or require further development. In some 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.

This section details the purpose, state, and future pressures for each of the 33 indicators that were analyzed. The authors of the indicator reports were asked to assess, in his or her best professional judgment, the overall status of the ecosystem component in relation to established endpoints or ecosystem objectives, when available. Five broad categories were used:

- **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.

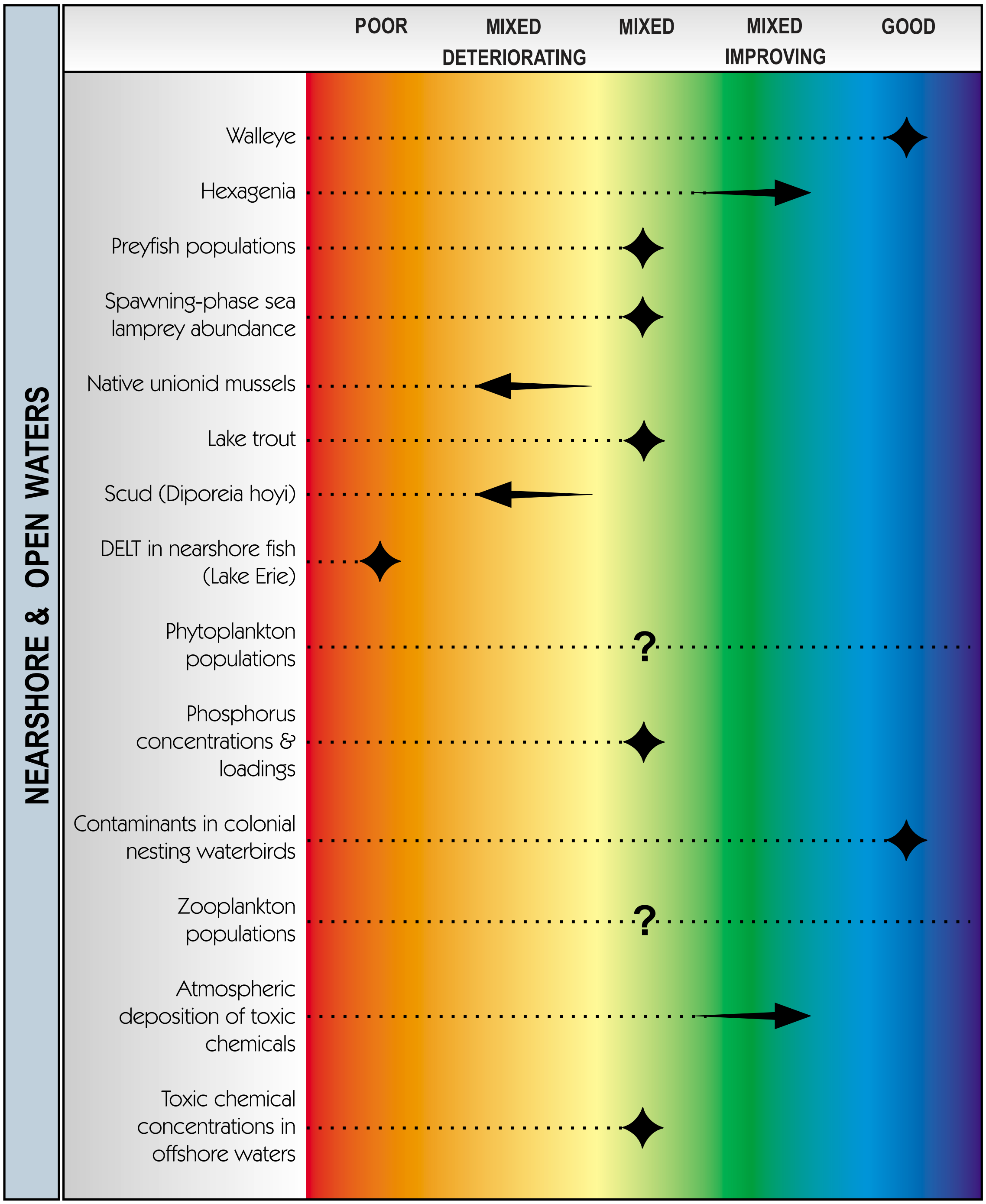
- **Poor.** The ecosystem component is severely negatively impacted and it does not display even minimally acceptable conditions.

Over the next several State of the Lakes Ecosystem Conferences, additional indicators will be developed, monitoring programs will be adjusted, information management systems put into place, and research and testing completed to refine the indicators. A robust suite of indicators will strengthen the biennial assessment of the status of the Great Lakes.

The Great Lakes community is encouraged to assist in this assessment by exploring the detailed indicator summaries and conclusions, and providing feedback on the content, format, conclusions, and implications for management. The complete indicator reports for these 33 indicators can be found in ***Implementing Indicators, November 2000.***

## 3.1 Nearshore & Open Waters

### Nearshore and Open Water Indicators - Assessment at a Glance

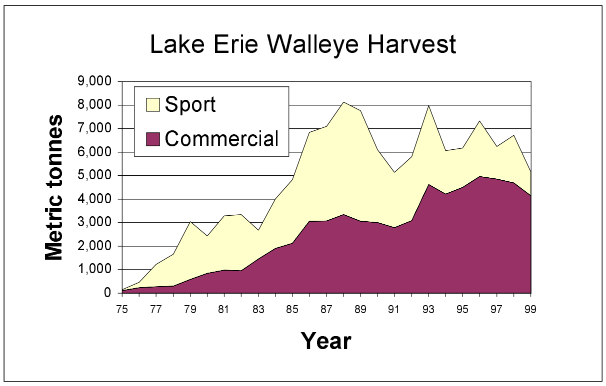


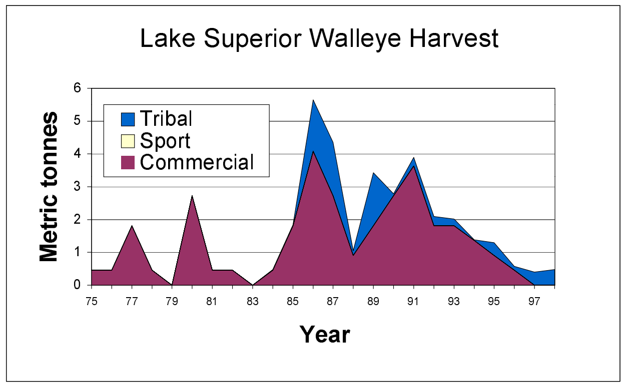
## alleye

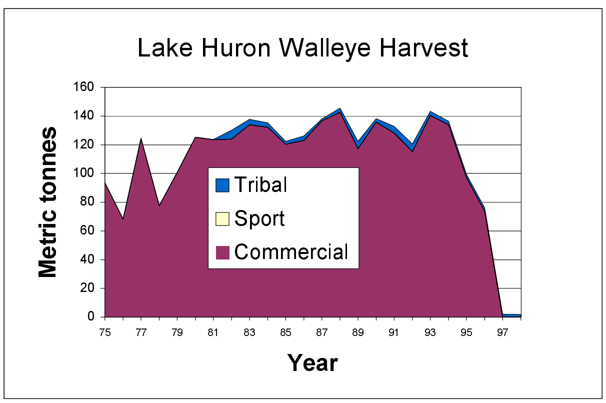
**Assessment**: Good

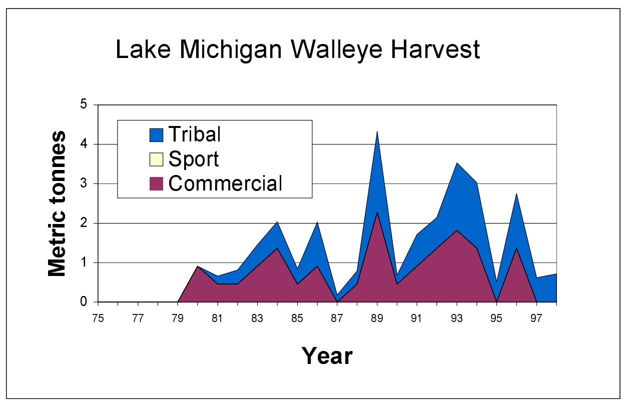
**Purpose**
Trends in the amount of walleye harvested indicate changes in overall fish community structure, the health of percids (the family of fish to which walleye belong), and the stability and resiliency of the Great Lakes aquatic ecosystem.

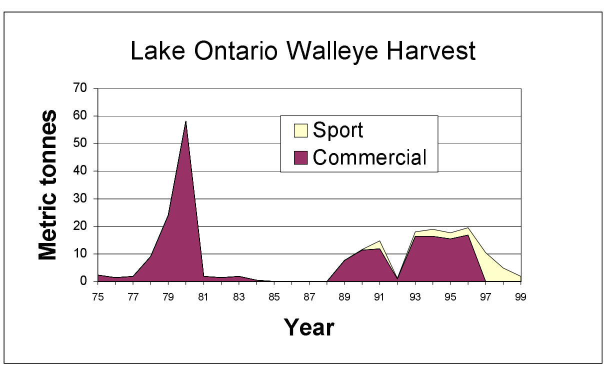
**State of the Ecosystem**
In general, walleye yields peaked during periods of environmental conditions that favoured walleye (mid-1980s), and they remain substantially improved from levels of the 1970s. Total yields were highest in Lake Erie, intermediate in Lakes Huron and Ontario, and lowest in Lakes Michigan and Superior, as shown by the historical pattern before the 1930s. Declines in the 1990s were likely related to shifts in environmental states, i.e., reduced nutrient levels in the water, changing fisheries, and, perhaps in Lake




Walleye harvests for each of the Great Lakes.
(Note: Established Fish Community Goals and Objectives are: Lake Huron: 700 metric tonnes, Lake Michigan: 100-200 metric tonnes, Lake Erie: sustainable harvests in all basins. Achievement of these targets will require healthy walleye stocks in each lake.)

Source: Tom Stewart (Lake Ontario-OMNR), Tom Eckhart (Lake Ontario-NYDEC), Dave Fielder (Lake Huron-MDNR), various annual OMNR and ODNR Lake Erie fisheries reports, and the GLFC commercial fishery data base

Erie, a population naturally coming into balance with its prey base.

**Future Pressures**
Walleye populations will be influenced by loss of habitats; environmental factors that alter water levels, water temperature, water clarity, and flow (currents); climate change impacts; non-native species, like zebra mussels, ruffe, and round gobies; and human disturbance of tributary and nearshore habitats through activities like dredging, diking, farming, and filling of wetlands.

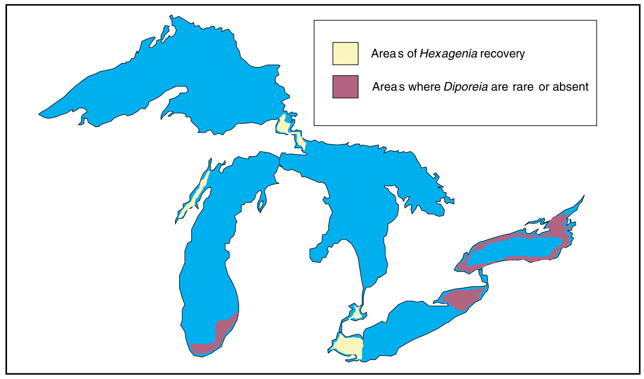
**Acknowledgments**
Author: Roger Knight, Ohio Department of Natural Resources.

Fishery harvest data were obtained from Tom Stewart (Lake Ontario-OMNR), Tom Eckhart (Lake Ontario-NYDEC), Karen Wright (Upper Lakes tribal data-COTFMA), Dave Fielder (Lake Huron-MDNR), Terry Lychwyck (Green Bay-WDNR), various annual OMNR and ODNR Lake Erie fisheries reports, and the GLFC commercial fishery data base. Gene Emond (ODNR) collated data into a standardized form. Fishery data should not be used for purposes outside of this document without first contacting the agencies that collected them.

## Assessment: Mixed, improving

**Purpose**
*Hexagenia* (or burrowing mayfly) is intolerant of pollution and thus reflects the quality of water and lakebed sediments in mesotrophic Great Lakes habitats (moderate nutrient levels). It was historically an important item in the diets of many valuable fishes, and the massive swarms of winged adults that are typical of healthy, productive *Hexagenia* populations are highly visible.

**State of the Ecosystem**
There is now evidence that *Hexagenia* have begun to recover in Green Bay (Lake Michigan), Saginaw Bay (Lake Huron), and the Western Basin of Lake Erie, and that they have fully recovered in the southwestern part of the Western Basin of Lake Erie. Most of Lake St. Clair and portions of the upper Great Lakes connecting channels support populations of *Hexagenia* with the highest biomass and production measured anywhere in North America. In sharp contrast, *Hexagenia* have been extirpated (eliminated) in polluted portions of these same Great Lakes waters and no recovery is presently evident. The recovery of *Hexagenia* in western Lake Erie is a signal which




Hexagenia recovery and Diporeia decline in the Great Lakes.
Source: Thomas Edsall, U.S. Geological Survey, Biological Resources Division, Ann Arbor, MI, unpublished data. Figure created by Melanie Neilson, Environment Canada

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

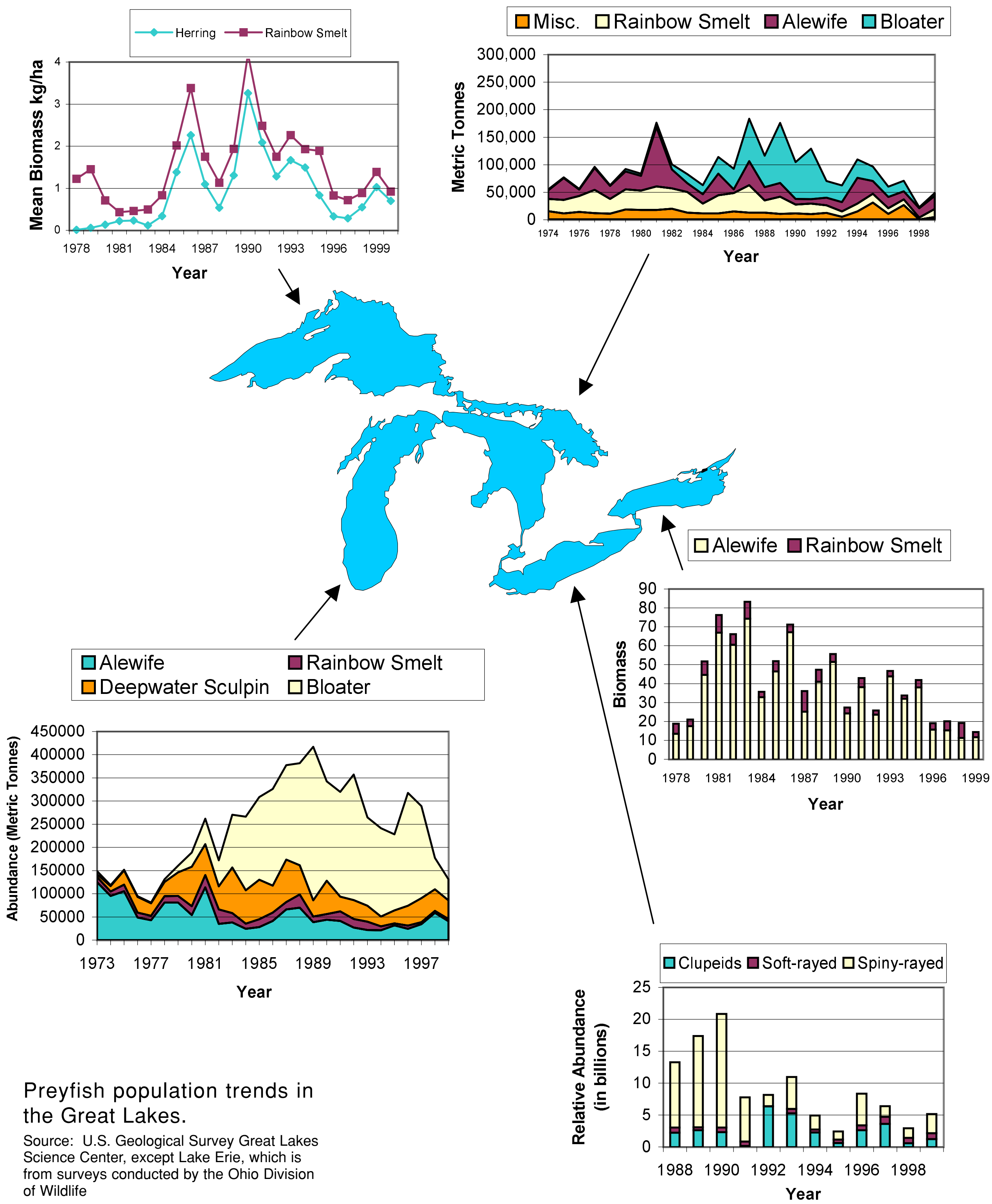
**Future Pressures**
*Hexagenia* are sensitive to periodic occurrences of anoxic (lacking oxygen) bottom waters resulting from excessive nutrient inputs; and toxic pollutants, including oil and heavy metals, which accumulate and persist in the lakebed sediments. Stormwater runoff from impervious surfaces and combined sewer overflows are significant sources of these pollutants.

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

## Assessment: Mixed

**Purpose**
This indicator directly measures the abundance and diversity of preyfish populations, especially in relation to the stability of predator species which are necessary to maintain the biological integrity of each lake.

**State of the Ecosystem**
***Lake Superior.*** The population of lake herring has declined in recent years, believed to be the result of environmental factors rather than parental stock size. In contrast, rainbow smelt biomass has remained




Preyfish population trends in the Great Lakes.

Source: U.S. Geological Survey Great Lakes Science Center, except Lake Erie, which is from surveys conducted by the Ohio Division of Wildlife low and is likely controlled by predation from trout and salmon. Sculpins remain at low but consistent levels of abundance.

***Lake Michigan.*** Alewives and smelt remain at lower levels than in previous years, apparently controlled in large part by predation pressure. Bloater biomass continues to decline due to lack of recruitment and slow growth. Sculpins continue to contribute a significant portion of the preyfish biomass.

***Lake Huron.*** The decline in bloater abundance has resulted in an increased proportion of alewives in the preyfish community. Predation pressure may be an important force in both alewife and rainbow smelt populations. Sculpin populations have varied over time, but have been at lower levels in recent years.

***Lake Erie.*** The preyfish community in Lake Erie has a high species diversity, but recently it has shown declining trends in all three basins. In the eastern basin, rainbow smelt (soft-rayed) have shown significant declines in abundance. In the western and central basins, white perch (spiny-rayed) and rainbow smelt have declined. Gizzard shad and alewife (clupeids) abundance has been quite variable across the survey period.

***Lake Ontario.*** Alewives and to a lesser degree rainbow smelt dominate the preyfish population. Alewives had declined to low levels; though this species has exhibited strong 1998 and 1999 year classes (a year class refers to all the fish of a particular species born that year) which have recently increased their abundance. Rainbow smelt show some increase due to influence of 1996 year class, but the scarcity of large individuals indicates heavy predation. Overall, shifts to deeper water have been noted in fish distributions and may be related to establishment of zebra mussels. Sculpin populations have declined and remained at low levels since 1990.

**Future Pressures**
Preyfish populations are likely to be impacted by predation by salmon and trout, pressures from *Dreissena* (zebra and quagga mussels) populations, and dramatic declines in *Diporeia* (scud) populations.

**Acknowledgments**
Author: Guy W. Fleischer, U.S. Geological Survey Great Lakes Science Center, Ann Arbor, MI.

Contributions from Robert O'Gorman and Randy W. Owens, U.S. Geological Survey Great Lakes Science Center, Lake Ontario Biological Station, Oswego NY, Charles Madenjian, Gary Curtis, Ray Argyle and Jeff Schaeffer, U.S. Geological Survey Great Lakes Science Center, Ann Arbor, MI, and Charles Bronte and Mike Hoff, U.S. Geological Survey Great Lakes Science Center, Lake Superior Biological Station, Ashland, WI., and Jeffrey Tyson, Ohio Div. of Wildlife Sandusky Fish Research Unit, Sandusky, OH.

All preyfish trend figures are based on annual bottom trawl surveys performed by U.S. Geological Survey Great Lakes Science Center, except Lake Erie, which is from surveys conducted by the Ohio Division of Wildlife.

## **Assessment:** Mixed

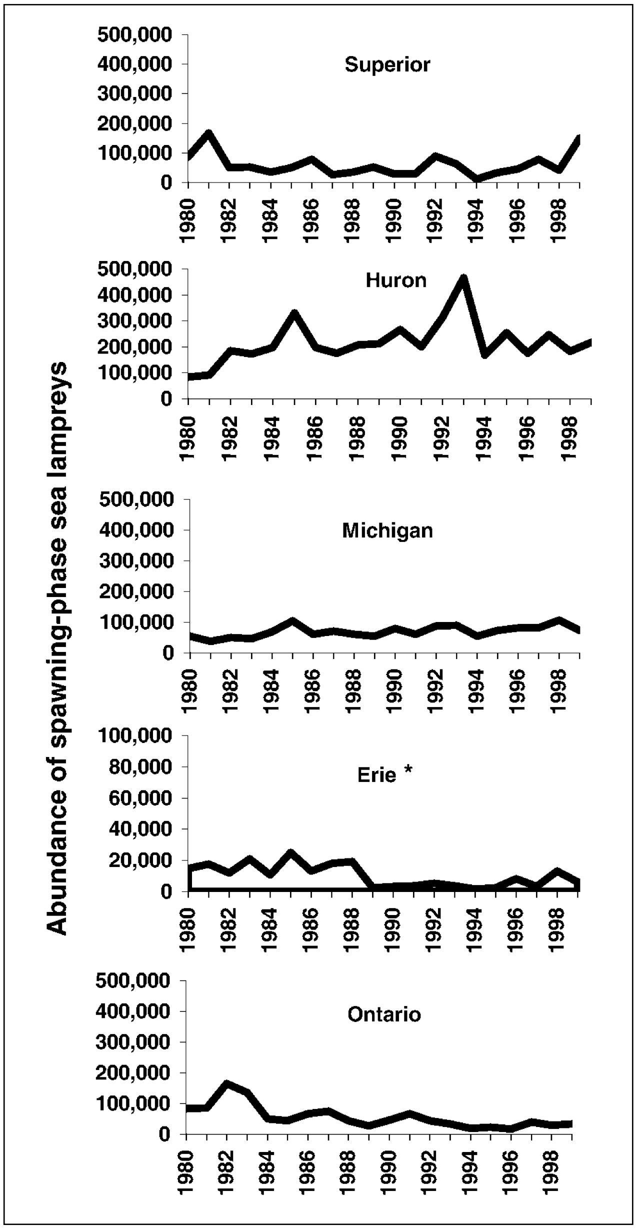
**Purpose**
This indicator estimates the abundance of sea lampreys in the Great Lakes, which has a direct impact on the structure of the fish community and health of the aquatic ecosystem. Populations of large, native, predatory fishes can be diminished by sea lamprey predation.

**State of the Ecosystem**
***Lake Superior.*** During the past 20 years populations have fluctuated but remain at levels less than 10% of peak abundance. Although there is concern that abundance has increased since 1995, survival objectives for lake trout continue to be met.

***Lake Michigan.*** Over most of the lake, populations have been relatively stable. However, an increase in the population in the north is caused by an expansion of the large population in Lake Huron moving into Lake Michigan.

***Lake Huron.*** During the early 1980s, populations increased, particularly in the north. Through the 1990s Lake Huron contained more sea lamprey than all the other lakes combined. Lake trout restoration activities were abandoned in the northern portion of the lake during 1995 because so few lake trout were surviving to maturity because of attacks by sea lamprey. An integrated control strategy was initiated in the St. Marys River in 1997, including targeted application of a new bottom-release lampricide, enhanced trapping of spawning animals, and sterile-male release.

***Lake Erie.*** Lamprey abundance has increased since the early 1990's to levels that threaten the lake trout success. An assessment during 1998 indicated that




Total lakewide abundance of sea lamprey estimated during the spawning migration. *Note the scale for Lake Erie is 1/5 larger than 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

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.

***Lake Ontario.*** Abundance of spawning-phase sea lampreys has continued to decline to low levels throughout the 1990s.

**Future Pressures**

As water quality improves in Great Lakes tributaries so does the potential for sea lampreys to colonize new locations. Short lapses in control can result in rapid increases in abundance. Significant additional control efforts, like those on the St. Marys River, may be necessary to maintain suppression.

**Acknowledgments**

Author: Gavin Christie, Great Lakes Fishery Commission, Ann Arbor, MI.

## **Assessment:** Mixed, deteriorating

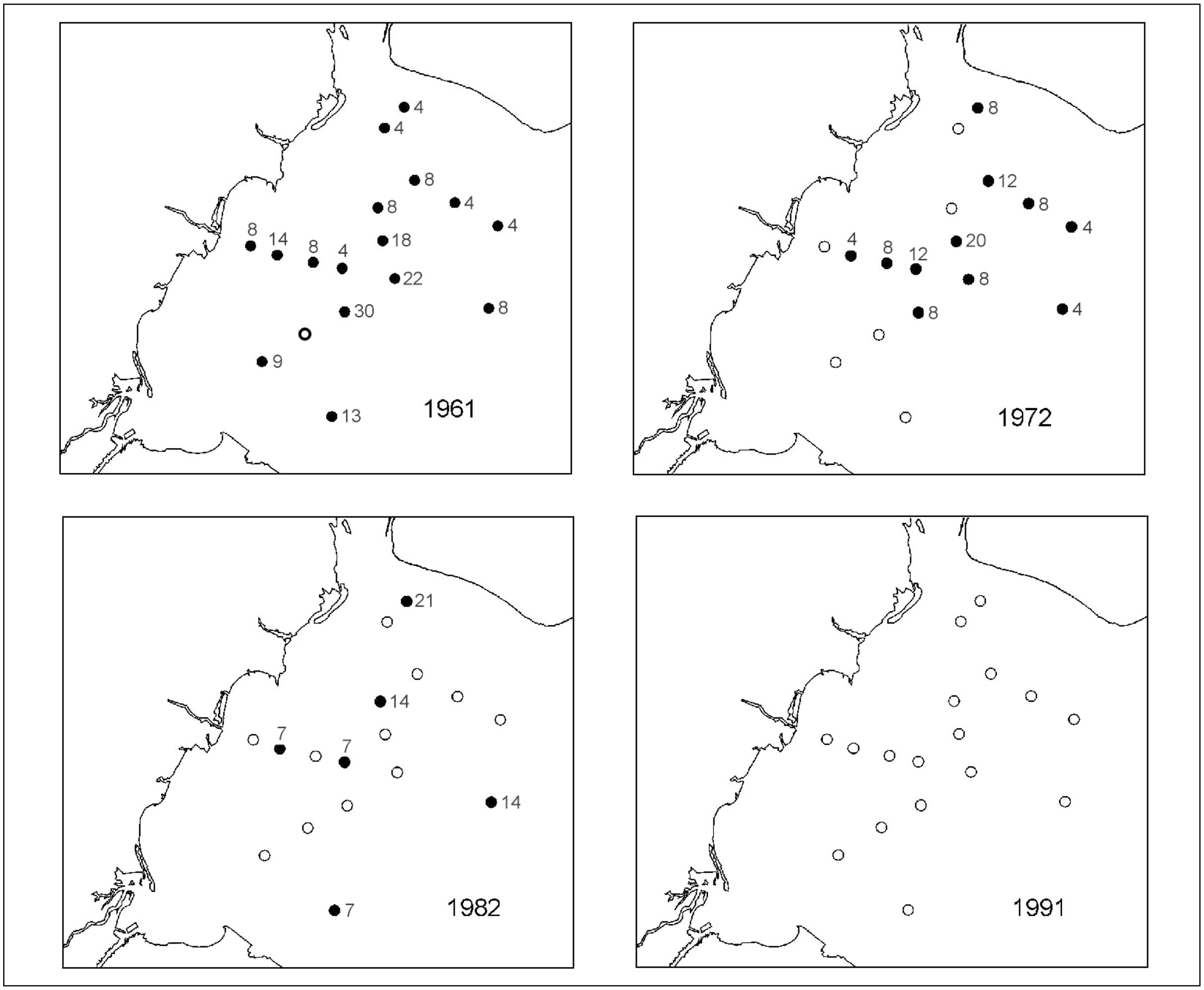
**Purpose**

Unionid distribution and abundance patterns reflect the general health of the aquatic ecosystem, and in particular those components interacting with the bottom substrates. Unionid mussels are long-lived, relatively sedentary animals, which are highly sensitive to habitat degradation, organic, inorganic, and metal pollutants, and biofouling by zebra mussels.

**State of the Ecosystem**

Many species of unionid mussels are listed as endangered or threatened. Most unionid populations in the Great Lakes and associated watersheds have declined as a result of decades of habitat alteration such as dredging, urbanization, increased sedimentation, and shoreline armouring. Additional stresses include changes in fish distribution, chemical pollutants in the water column and sediments and the arrival of competitive and predatory non-native species.

Unionid species diversity and density have severely declined in the open waters of Lake Erie, the Detroit River, and Lake St. Clair since the arrival of zebra mussels in the mid-1980s. Many sites do not contain any live unionids. Healthy and diverse




Abundance of freshwater mussels (numbers/$m^2$) collected in 1961, 1972, 1982 and 1991 from 17 sites in the western basin of Lake Erie. Black circles indicate the presence of native unionid mussels and the number indicates the quantity found at the test site. White circles indicate the absence of native unionid mussels.

Source: T. Nalepa, National Oceanic and Atmospheric Administration, B. Manny, J. Roth, S. Mozley, and D. Scholesser

communities, however, were recently discovered in Lake Erie in nearshore areas with firm substrates, in soft sediments associated with coastal marshes, and in a coastal marsh in the St. Clair River delta.

**Future Pressures**

Pressures on the native unionid mussel populations include: zebra mussel expansion (biofouling); changes to native fish community structure by non-native species (unionid reproductive cycles contain a parasitic larval stage requiring specific fish hosts); increasing urban sprawl; development of factory farms; and elevated use of herbicides.

**Acknowledgments**

Authors: S. Jerrine Nichols, U.S. Geological Survey Great Lakes Science Centre, Ann Arbor, MI and Janice Smith, Environment Canada, Burlington, ON.

## rout

**Assessment:** Mixed

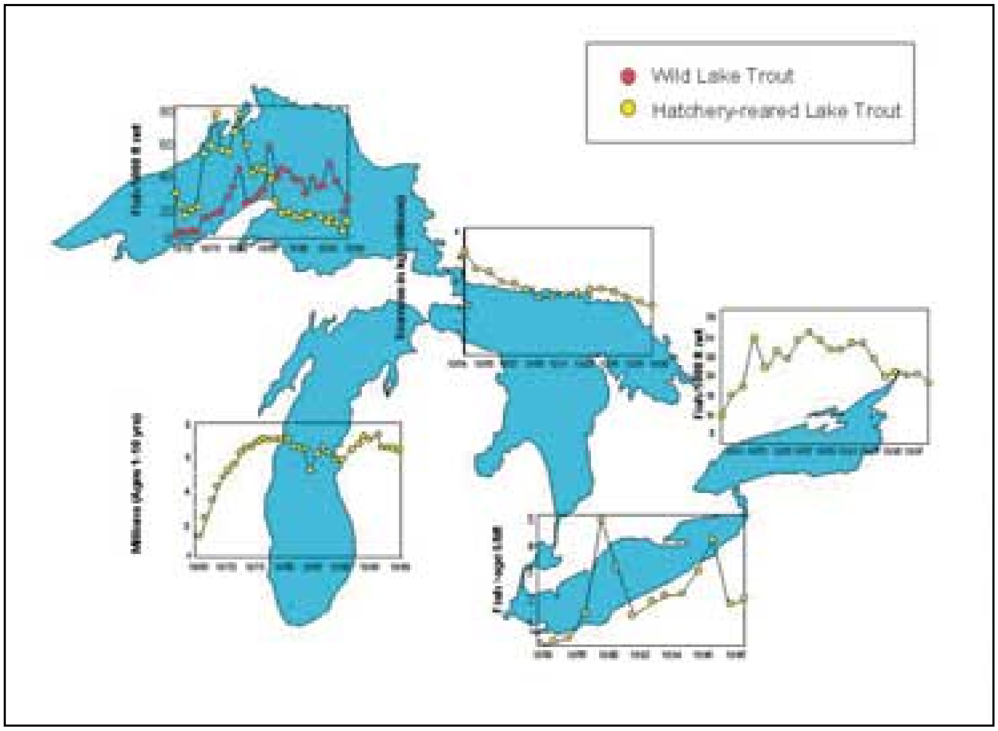
**Purpose**
This indicator tracks the status and trends in lake trout populations, and it will be used to infer the basic structure of cold water predator and prey communities and the general health of the ecosystem. By the late 1950s, lake trout were extirpated throughout most of the Great Lakes. Full restoration will not be achieved until natural reproduction is re-established and maintained.

**State of the Ecosystem**
Lake trout abundance dramatically increased in all the Great Lakes shortly after the initiation of sea lamprey control, stocking, and harvest control. Natural reproduction is now widespread in Lake Superior, and stocking has been discontinued throughout most of the lake. Densities of wild fish have exceeded that of hatchery-reared fish since the mid 1980s. Unfortunately natural reproduction is at very low levels or non-existent in the rest of the Great Lakes, therefore populations in these waters are maintained solely by stocking.

**Future Pressures**
Predation on newly hatched lake trout larvae by native and non-native predators is a problem. Excessive sea lamprey predation will result in few fish reaching sexual maturity. Hatchery-reared fish appear unable to select suitable substrate for egg deposition and genetic diversity is lacking in the strains of hatchery-reared fish stocked into the Lakes. Early mortality syndrome (EMS) of fish larvae is thought to be due to thiamine deficiencies in the parental diet of alewives.

**Acknowledgments**
Author: Charles Bronte, U.S. Fish and Wildlife Service, Green Bay, WI.

Contributions by James Bence, Michigan State University, East Lansing, MI, Donald Einhouse, New York Department of Environmental Conservation, Dunkirk, NY, and Robert O'Gorman, U.S. Geological Survey, Oswego, NY.

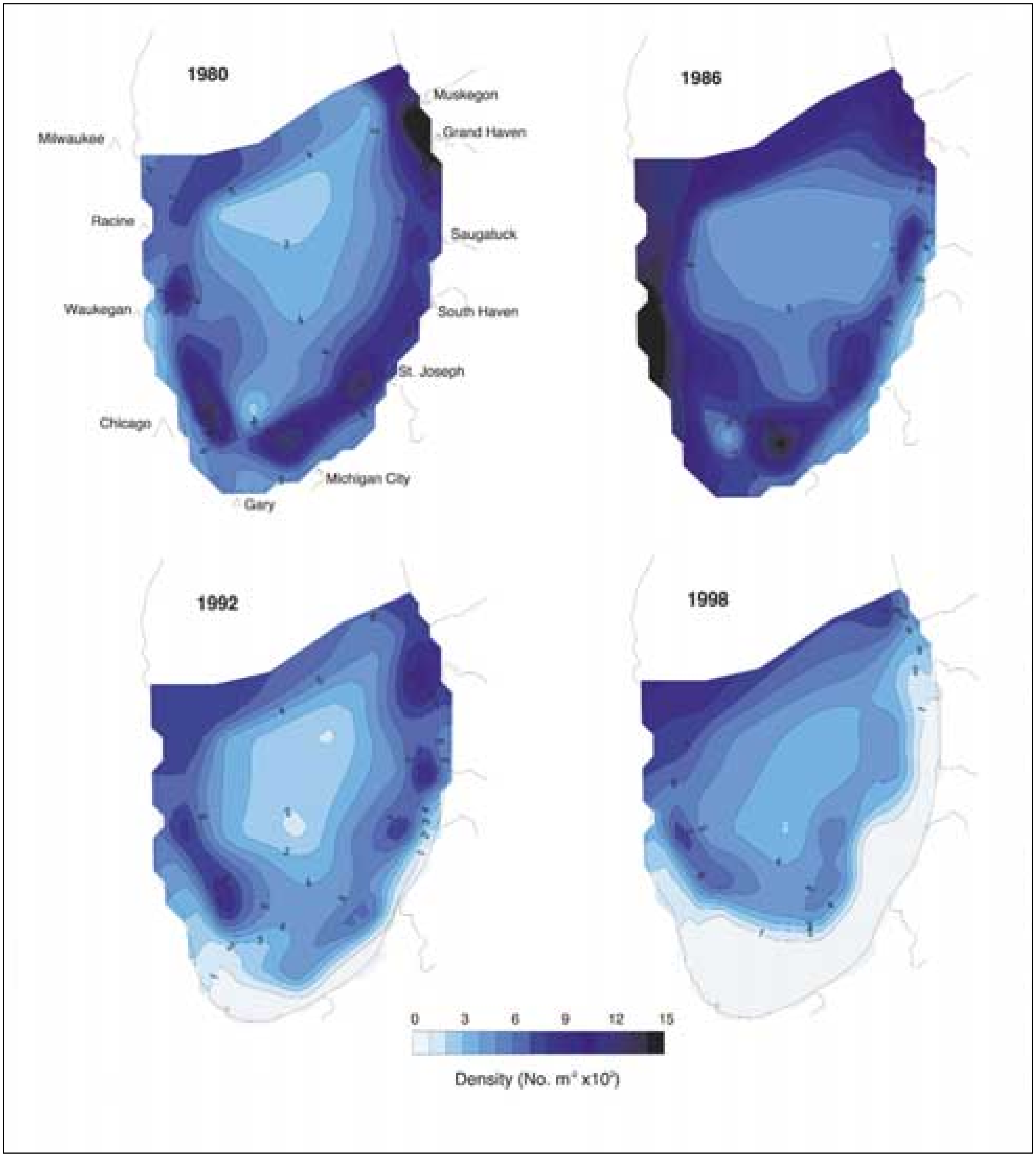



Lake trout abundance in the Great Lakes.
Source: R.L. Eshenroder, Great Lakes Fishery Commision, J.W. Peck, and C.H. Olver

## *(Diporeia hoyi)*

**Assessment:** Mixed, deteriorating

**Purpose**
This indicator provides a measure of the biological integrity of the offshore regions of the Great Lakes. It consists of assessing the abundance of the benthic macroinvertebrate *Diporeia*, which are the most abundant benthic organisms in cold, offshore regions of each of the lakes, and which are a key component in the food web of offshore regions.




Density (numbers/m$^2$ x 10$^3$) of Diporeia in the southern basin of Lake Michigan between 1980 and 1998. Note recent declines in the southeastern portion of the basin.

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

**State of the Ecosystem**
Populations of *Diporeia* have been observed to decline shortly after zebra mussels become established. *Diporeia* are currently declining in portions of Lake Michigan, Lake Ontario, and eastern Lake Erie (see the figure with the *Hexagenia* indicator report - page 29). Areas where *Diporeia* are known to be rare or absent include the southeastern portion of Lake Michigan from Chicago to Grand Haven at water depths < 70 metres, all of Lake Ontario at depths < 70 metres except for some areas along the northern shoreline, and all of the eastern basin of Lake Erie. In other areas of Lakes Michigan and Ontario, *Diporeia* are still present, but abundances have decreased by one-half or more. Populations appear to be stable in Lake Superior. Recent evidence suggests that the reason for the decline of *Diporeia* may be related to the infestation of zebra mussels.

**Future Pressures**
Expansion of zebra and quagga mussel populations at water depths of 30-50 metres will pose a threat to *Diporeia*.

**Acknowledgments**
Author: Thomas Nalepa, National Oceanic and Atmospheric Administration, GLERL, Ann Arbor, MI.

## Deformities, Eroded Fins, Lesions and Tumours (DELT) in Nearshore Fish

**Assessment:** Poor

**Purpose**
This indicator assesses the prevalence of external anomalies in nearshore fish. It will be used to infer areas where fish are exposed to contaminated sediments within the Great Lakes.

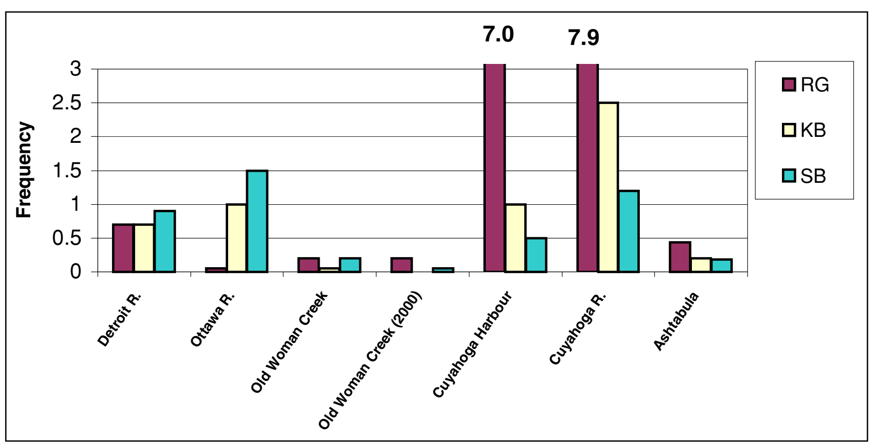
***Editor's Note:***
*The DELT Index (deformities, eroded fins, lesions, and tumours) was developed as a measure for the Index of Biological Integrity (IBI), and it has been included as one of the SOLEC indicators. Although the DELT index looks at the entire fish community, its inclusion of all species and age groups lessens its discriminatory power in distinguishing amongst levels of contaminant exposure of fish from various tributaries.*

*As an alternative indicator, the ELF Index (external lesion frequency) is being developed as an estimate of contaminant exposure of mature fish in a single species. Brown bullhead have been used to develop the index, since they are the most frequently used benthic indicator species in the southern Great Lakes. Information is included here to assist an evaluation of ELF as a SOLEC indicator.*

**State of the Ecosystem**
Field and laboratory studies have correlated chemical carcinogens found in sediments at some Areas of Concern in Lakes Erie, Michigan, and Huron with an elevated incidence of liver and external tumours. Other external anomalies may also be related to exposure to toxic chemicals, but their use must be carefully evaluated.

The most common external anomalies found in bullhead over the last twenty years are raised growths (RG) on the body or lips (often called tumours), focal discoloration (called melanistic spots), and stubbed or shortened/missing barbels (SB). Knobbed barbels (KB) have not been as consistently reported in the historical database, but also appear to be a useful parameter.

Preliminary findings from bullhead populations in several Lake Erie contaminated tributaries and a




External lesion frequency for brown bullheads in Lake Erie, 1999-2000. RG-raised growth, KB-knobbed barbels, SB-stubbed barbels.

Source: Lake Erie Ecological Investigation, unpublished. P. Baumann, U.S. Geological Survey, and D. Peterson, Ohio State University reference site indicate that single anomalies occurring at > 0.4 per fish or multiple anomalies occurring at greater than 0.8 per fish would indicate possible impairment.

**Future Pressures**

Continued exposure of the fish populations to contaminated sediments could cause deformities to persist.

**Acknowledgments**

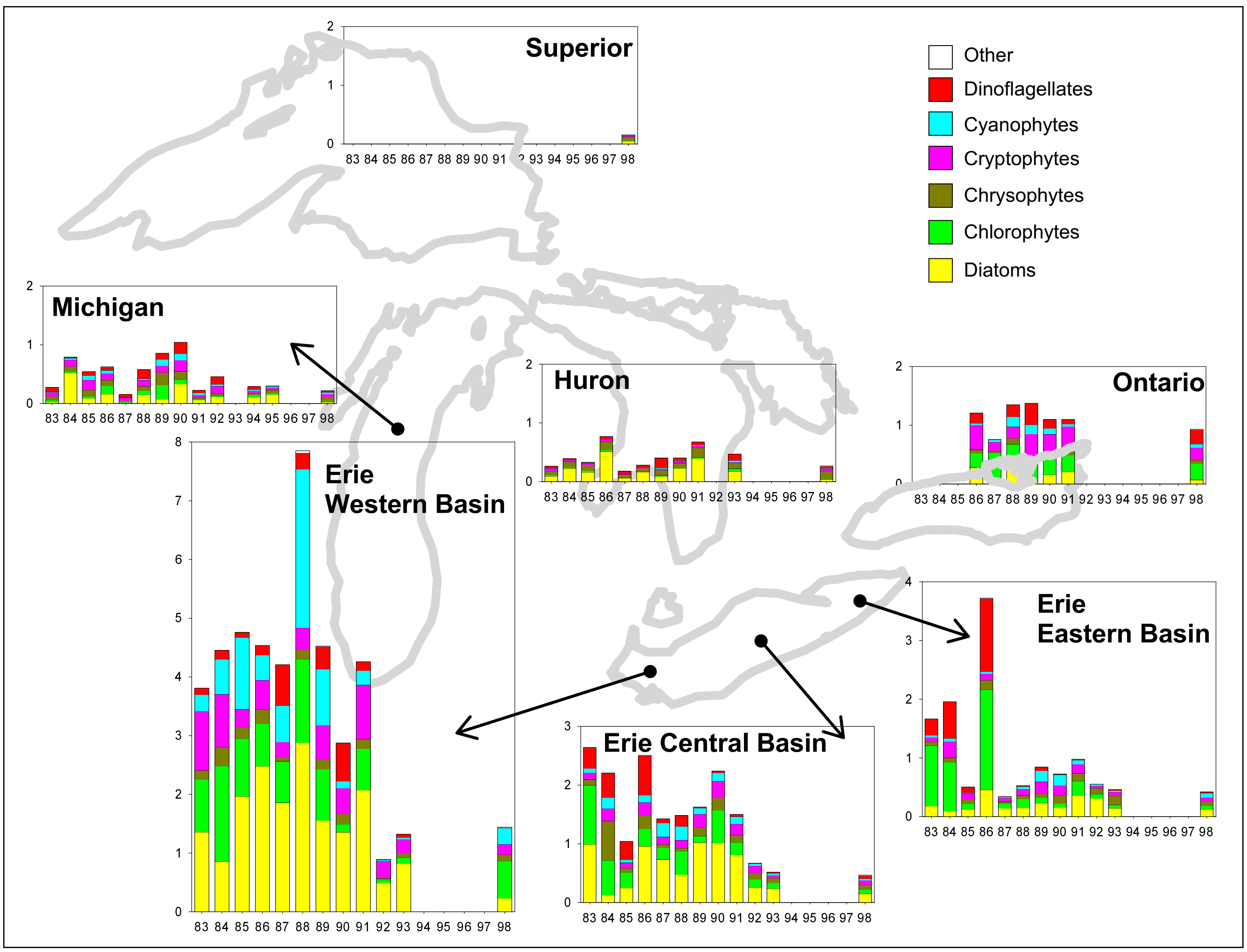
Authors: Stephen B. Smith, U.S. Geological Survey, Biological Resources Division, Reston, VA, and Paul C. Baumann, U.S. Geological Survey, Biological Resources Division, Columbus, OH.

## Phytoplankton Populations

**Assessment:** Unable to assess status until targets are determined

**Purpose**

This indicator involves the direct measurement of phytoplankton species composition, biomass, and primary productivity 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.




Phytoplankton biovolume (gm/m$^3$) and community comparison in the Great Lakes 1983-1998 (summer, open lake, epilimnion or upper waters). Blank indicates no data.

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

**State of the Ecosystem**
Substantial reductions in summer phytoplankton populations occurred in the late 1980s in the eastern basin of Lake Erie and in the early 1990s for the central and western basins. The data were highly variable year-to-year, so possible changes in community composition were not determined. In general, phytoplankton biomass in Lake Michigan was lower in the 1990s than in the 1980s. The timing of these declines in phytoplankton biomass suggest the possible impact of zebra mussels. No trends are apparent in phytoplankton biomass in Lakes Huron or Ontario.

**Future Pressures**
Pressures on phytoplankton include changes in nutrient loadings; continued introductions and/or expansions of non-native species.

**Acknowledgments**
Authors: Richard P. Barbiero, DynCorp I&ET, Alexandria, VA, and Marc L. Tuchman, U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.

**Assessment:** Mixed

**Purpose**
This indicator assesses total phosphorus levels in the Great Lakes, and it is used to support the evaluation of trophic status and food web dynamics in the Great Lakes. Phosphorus is an essential element for all organisms and is often the limiting factor for aquatic plant growth 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 harbours.

Average concentrations in the open waters of Lakes Superior, Michigan, Huron, and Ontario are at or below guideline levels. Concentrations in all three basins of Lake Erie exceed phosphorus guidelines and recent data suggest an increasing trend, however, this may be an effect of large populations of non-native zebra and quagga mussels. Further research is necessary. In Lakes Ontario and Huron, almost all offshore waters meet the desired guideline although some nearshore areas and embayments showed elevated levels which could promote nuisance algae growths such as the attached green algae, *Cladophora*.

**Future Pressures**
Current control measures may no longer be sufficient because increasing numbers of people living along the Lakes will exert increasing demands on existing sewage treatment facilities, and additional loadings can be expected.

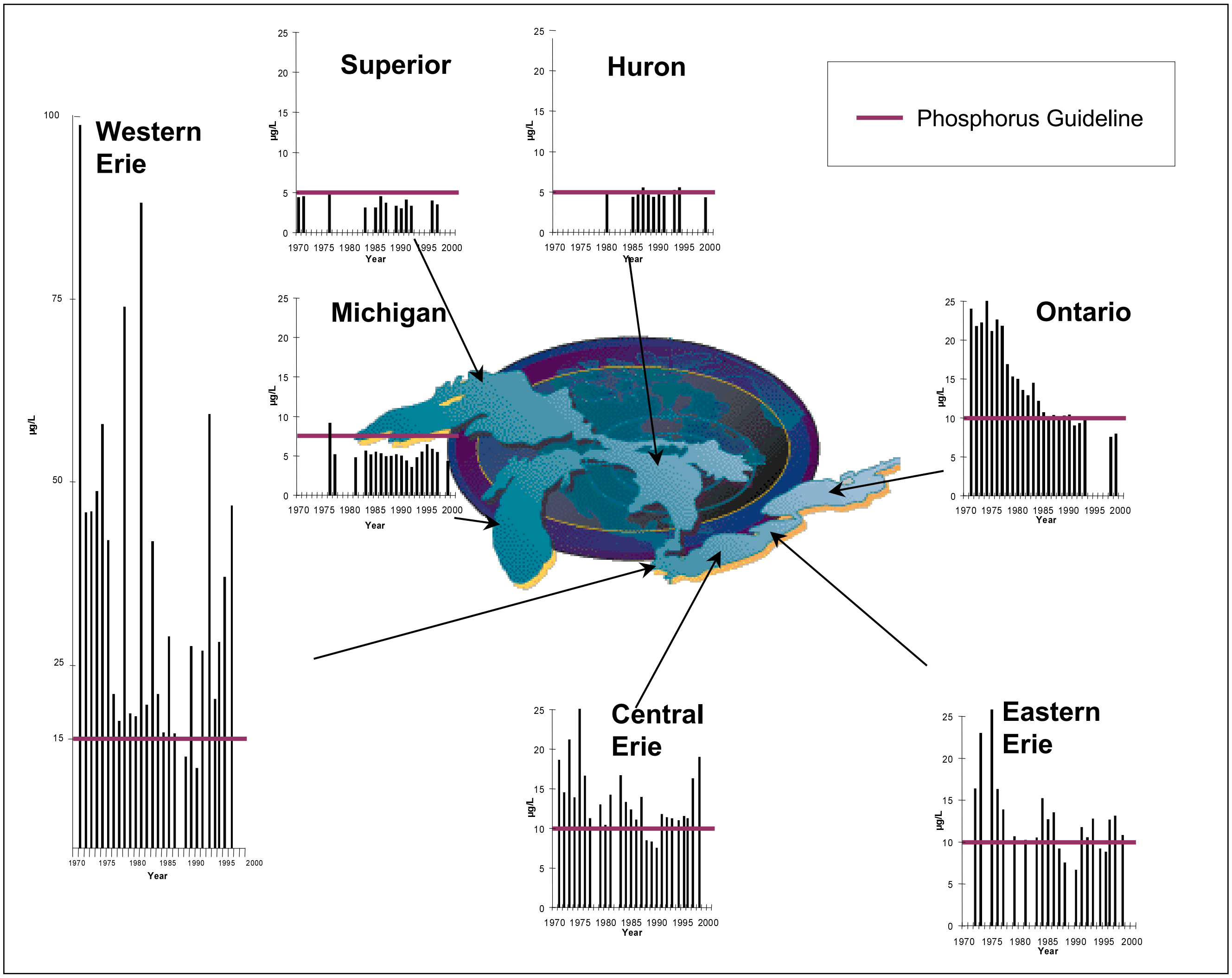
**Acknowledgments**
Authors: Scott Painter, Environment Canada, Environmental Conservation Branch, Burlington, ON, and Glenn Warren, U.S. Environmental Protection Agency, Great Lakes National Programs Office, Chicago, IL.

## Contaminants in Colonial Nesting Waterbirds

**Assessment:** Good

**Purpose**
This indicator assesses current chemical concentration levels 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 the impact of contaminants on the health of the waterbird populations.

**State of the Ecosystem**
Most contaminants in herring gull eggs have declined by a minimum of 50% and many have declined more than 90% since monitoring began in 1974. As well, the rate of decline in more than 70% of cases is as fast or faster than in the past. Gull eggs from Lake Ontario and the St. Lawrence River continue to have the greatest levels of mirex and dioxin (2,3,7,8 TCDD), those from the upper lakes have the greatest levels of dieldrin and heptachlor epoxide, those from Lake Michigan have the greatest levels of DDE and those from Lake Michigan and the Detroit River-Western Lake Erie area have the greatest levels of PCBs.




Total phosphorus trends in the Great Lakes 1971-2000 (spring, open lake, surface). Blank indicates no sampling.

Source: Environmental Conservation Branch, Environment Canada and U.S. Environmental Protection Agency, Great Lakes National Program Office

Populations of most species have increased over those of 25-30 years ago. Interestingly, Double-crested Cormorants, whose population levels have increased more than 400-fold, still exhibit some eggshell thinning.

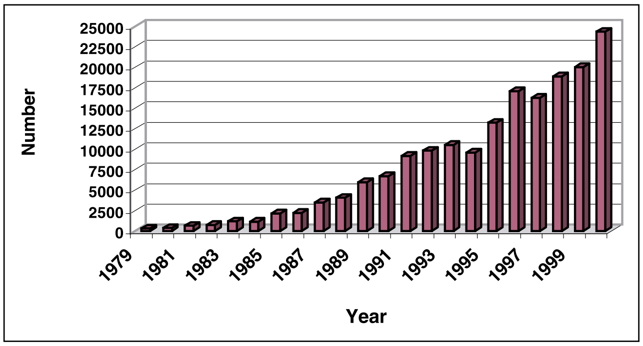
**Future Pressures**

All contaminants entering the Great Lakes including those from re-suspension of contaminated sediments, atmospheric inputs, and underground leaks from landfill sites, will continue to put pressure on colonial nesting waterbirds.

**Acknowledgments**

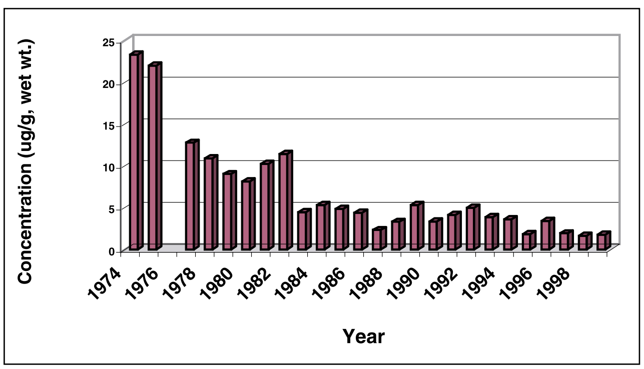
Author: D.V. Chip Weseloh, Canadian Wildlife Service, Environment Canada, Downsview, ON.

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, Que.) and wildlife biologists Ray Faber, Ralph Morris, Jim Quinn, John Ryder, Brian Ratcliff and Keith Grasman for egg collections, preparation, analysis and data management over the 27 years of this project.



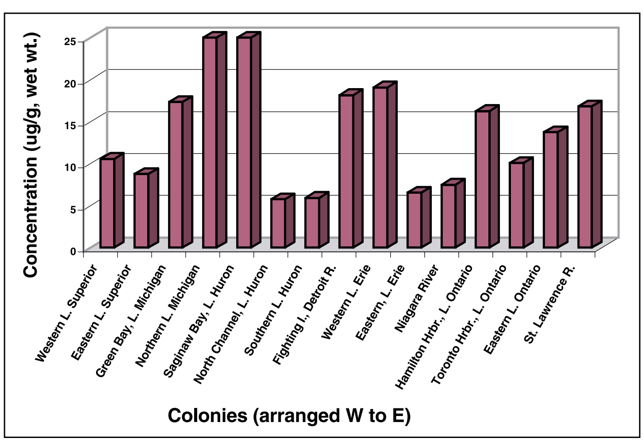

Double-crested Cormorant nests (breeding pairs) in Lake Ontario (1979-2000). Temporal trends.

Source: C. Pekarik and D.V. Weseloh, Canadian Wildlife Service, unpublished




DDE in Herring Gull eggs, Toronto Harbour 1974-1999. Spatial trends.

Source: C. Pekarik and D.V. Weseloh, Canadian Wildlife Service, unpublished




PCBs in Great Lakes Herring Gull eggs, 1999. Population trends.

Source: Canadian Wildlife Service, unpublished

## Zooplankton Populations

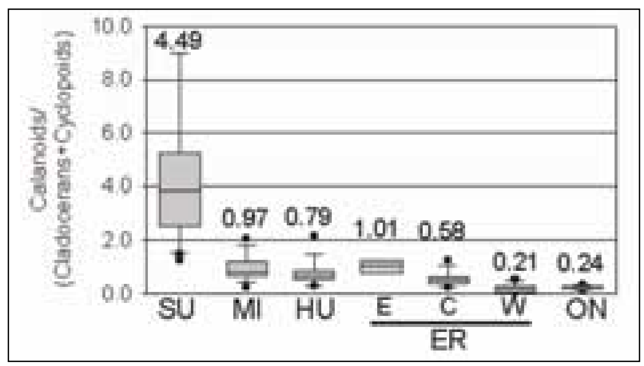
**Assessment:** Unable to assess status until targets are determined

**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 changes in food-web dynamics due to changes in vertebrate or invertebrate predation.

**State of the Ecosystem**

This indicator should provide information on the biological integrity of the Great Lakes. However, since specific targets or endpoints for this indicator have yet to be identified, it will be hard to determine whether conditions are improving or deteriorating.




Ratio of biomass of calanoid copepods to that of cladocerans and cyclopid copepods for the five Great Lakes. Lake Erie is divided into western, central and eastern basins.
(Data collected with 153 µm mesh net tows to a depth of 100 metres or 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)

The ratio of calanoids to cladocerans and cyclopoids (different groups of zooplankton) showed a clear relationship with trophic state of the waters. The average value for the oligotrophic (low nutrient levels) 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 both low, while the central basin of Lake Erie had an intermediate value. In the western and central basins of Lake Erie, a significant increase in the ratio of calanoids to cladocerans and cyclopoids was observed between 1970 and 1983-1987, and this increase was sustained throughout the 1990s.

**Future Pressures**
Zooplankton populations will continue to be affected by invasive non-native species, e.g., the spiny water flea and the fishhook water flea, and continued proliferation of zebra and quagga mussel populations.

**Acknowledgments**
Authors: Richard P. Barbiero, DynCorp I&ET, Alexandria, VA, Marc L. Tuchman, U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago IL, and Ora Johannsson, Fisheries and Oceans Canada, Burlington, ON.

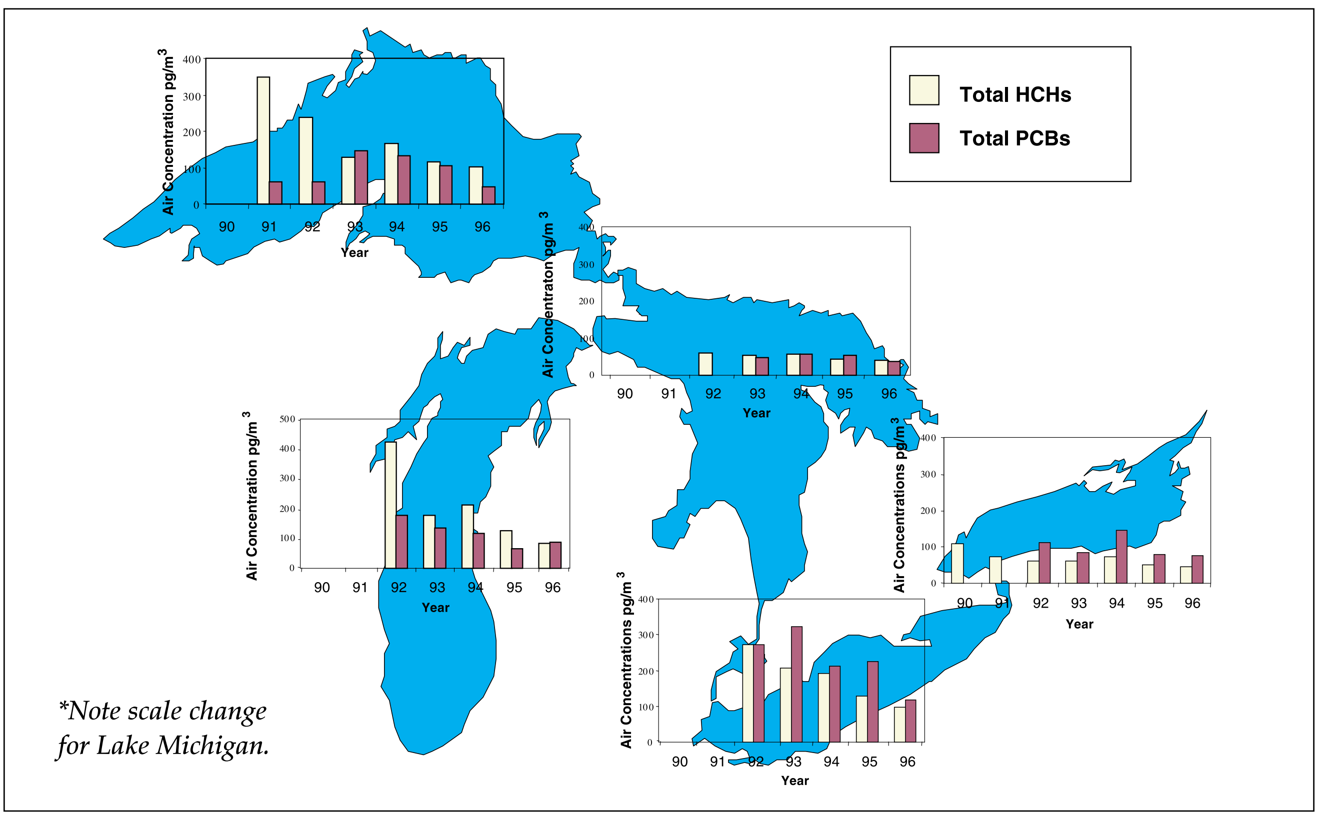
## oxic Chemicals

**Assessment:** Mixed, improving

**Purpose**
This indicator estimates the annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes, and it is used to determine temporal trends in contaminant concentrations.

**State of the Ecosystem**
The Integrated Atmospheric Deposition Network (IADN) consists of five master sampling sites, one near each of the Great Lakes, and several satellite stations. The data set is large, and only selected data are presented here.

For gas-phase total PCBs (polychlorinated biphenyls), elevated concentrations were consistently observed at the Lake Erie site compared to the other Lakes. For all sites, the trend over time is generally

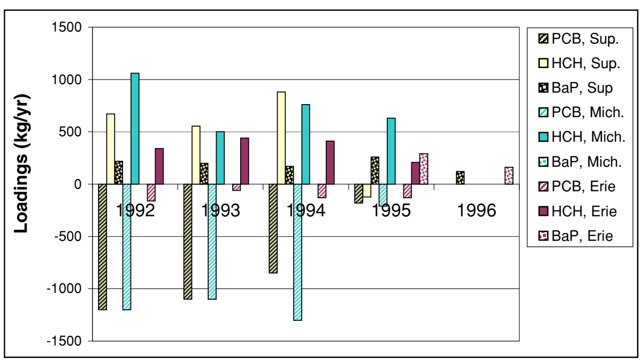



Atmospheric concentration of total PCB and total HCH.
Source: Integrated Atmospheric Deposition Network Steering Committee (2000)

downward. Total PCB concentrations at a satellite site in downtown Chicago were about 10 times higher than at the more remote sites.

Gas-phase α- and γ-HCH (hexachloro-cyclohexane) concentrations declined at all sites until 1996. γ-HCH (lindane) is a pesticide used as a seed treatment in the United States and Canada, and atmospheric concentrations may not decrease further.

The loadings from the atmosphere to the Great Lakes for total PCB, HCH, and BaP (Benzo-[*a*]-pyrene) are displayed in the accompanying figure. A negative bar indicates that the lake is vaporizing the compound to the atmosphere. A missing bar indicates that the loading could not be calculated, not that the loading was zero. These data show that the loadings are generally getting smaller and the lake water and the air above it are getting closer to being in equilibrium.




Loadings of Total PCBs, Total HCHs, and BaP to the Great Lakes.

Source: Integrated Atmospheric Deposition Network Steering Committee (2000)

**Future Pressures**

Atmospheric loadings of toxic compounds are likely to continue well into the future.

**Acknowledgments**

Ron Hites and Ilora Basu at Indiana University prepared this report on behalf of the IADN Steering Committee.

## Toxic Chemical Concentrations in Offshore Waters

**Assessment:** Mixed

**Purpose**

This indicator reports the concentration of toxic chemicals in offshore waters, and it 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. Examples of only a few illustrate spatial and temporal trends from a single source of information.

Organochlorine pesticides such as lindane and dieldrin are observed at relatively similar concentrations in all lakes and connecting channels. Concentrations decreased by approximately 50% between 1986 and 1996, but dieldrin still far exceeds the most sensitive water quality criterion for the protection of human consumers of fish.

Hexachlorobenzene (HCB), octachlorostyrene, and mirex are chemicals whose presence is due to historical localized sources. Concentrations of all three in the Niagara River have decreased by more than 50% between 1986 and 1996. However, both HCB and mirex continue to exceed the most stringent criteria for the protection of human consumers of fish.

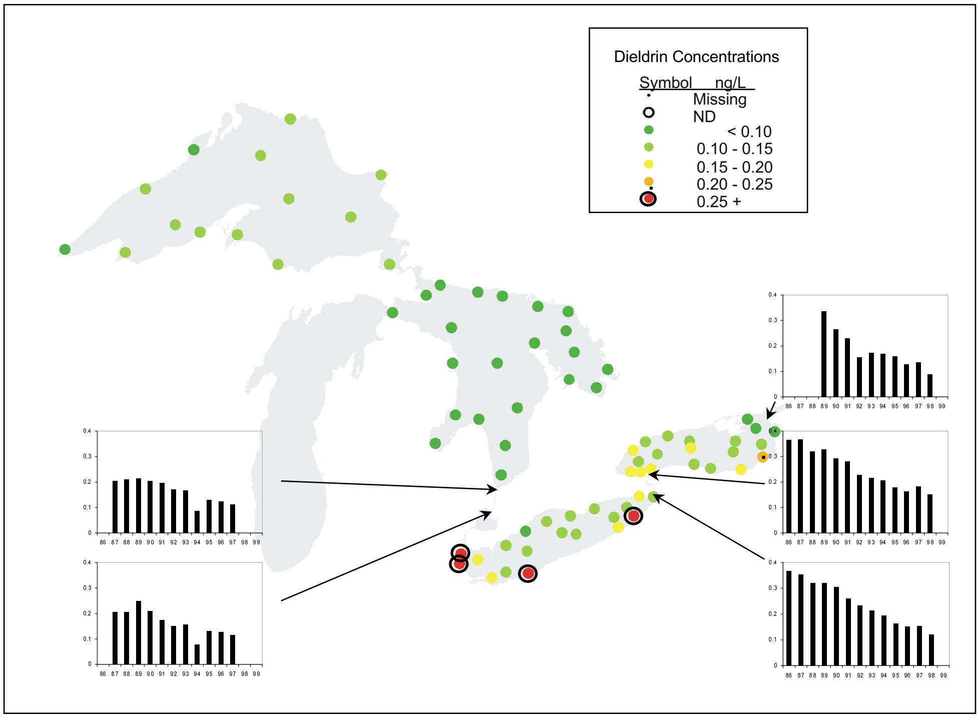
Concentrations of some (not all) polycyclic aromatic hydrocarbons (PAHs) appear to be increasing, suggesting localized sources. For example, comparisons of upstream/downstream concentrations of fluoranthene over time suggest increasing inputs from localized sources in the Niagara River.

**Future Pressures**

Active sources for some chemicals still exist; classes of chemicals such as endocrine disrupting chemicals, in-use pesticides, and pharmaceuticals are emerging issues.

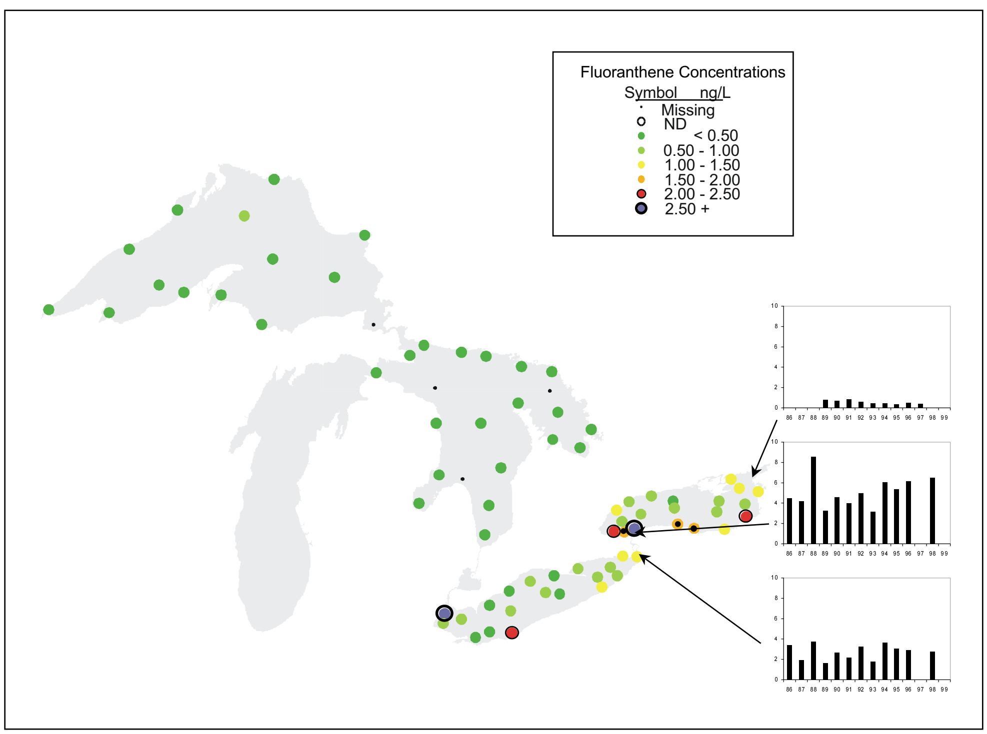
**Acknowledgments**

Author: Scott Painter, Environment Canada, Environmental Conservation Branch, Burlington, ON.




Spatial dieldrin patterns in the Great Lakes (spring 1997 or 1998, surface) and annual most likely estimated averages for the interconnecting channels from 1986 to 1998. Units = ng/L

Source: Environmental Conservation Branch, Environment Canada

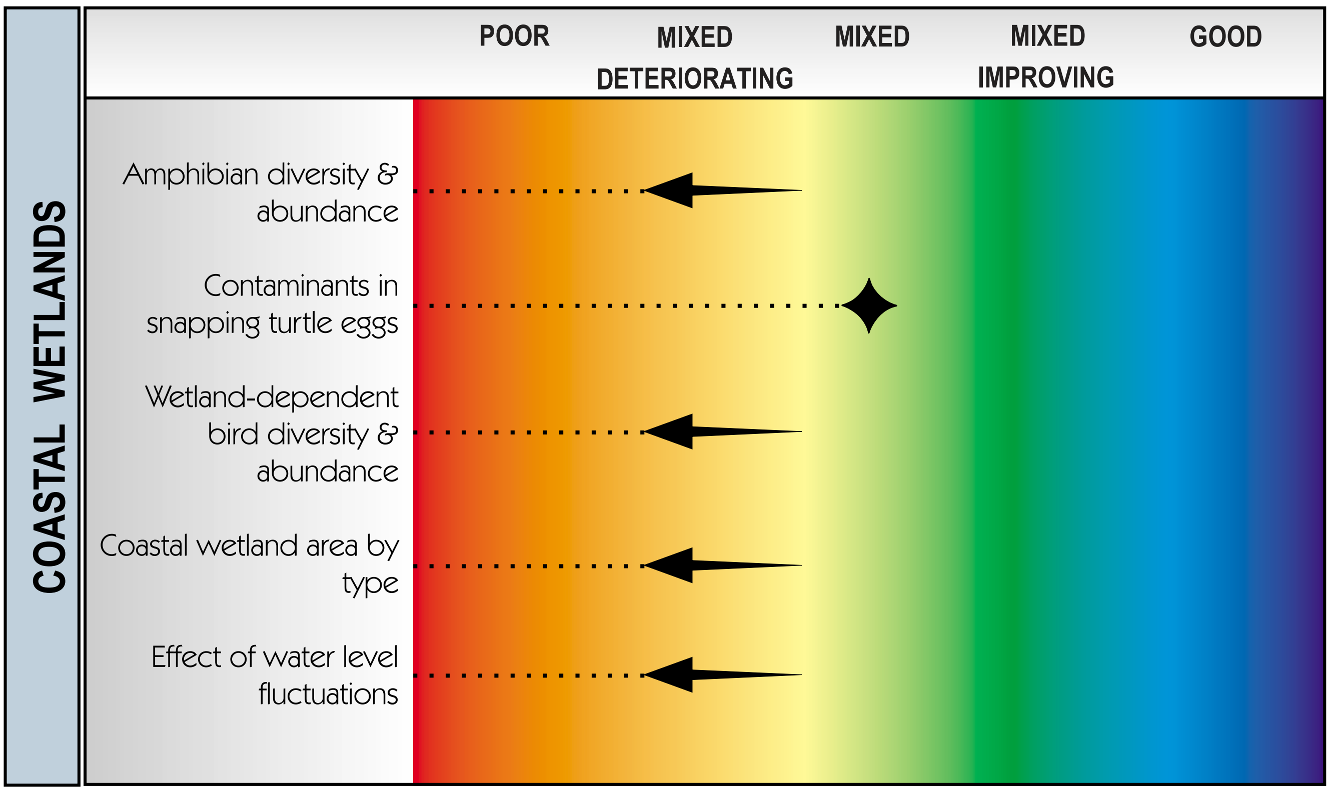



Spatial fluoranthene patterns in the Great Lakes (spring 1997 or 1998, surface) and annual most likely estimated averages for the interconnecting channels from 1986 to 1998. Units = ng/L

Source: Environmental Conservation Branch, Environment Canada

# 3.2 Coastal Wetlands

## Coastal Wetland Indicators - Assessment at a Glance




### Amphibian Diversity and Abundance

**Assessment:** Mixed, deteriorating

**Purpose**
Assessments of the species composition and relative abundance of calling frogs and toads are used to help infer the condition of Great Lakes basin marshes (i.e. wetlands dominated by non-woody emergent plants).

**State of the Ecosystem**
With only five years of data collected across the Great Lakes basin, the Marsh Monitoring Program (MMP) is quite new as a monitoring program. From 1995 through 1999, 11 frog and two toad species were recorded by MMP participants surveying 354 routes across the Great Lakes basin. Spring Peeper was the most frequently detected species. Green Frog was detected in more than half of station years. Gray Treefrog, American Toad and Northern Leopard Frog were also common.

Although some trends were suggested for species such as American Toad and Bullfrog, only the declining trend for Chorus Frog could be resolved with statistical confidence. Anecdotal and research evidence suggests that wide variations in the occurrence of many amphibian species at a given site is a natural and ongoing phenomenon.

**Future Pressures**
Threats to amphibians include habitat loss and deterioration, water level stabilization,

| Species Name | % station-years present* | Average calling code |
|---|---|---|
| Spring Peeper | 69 | 2.5 |
| Green Frog | 56.6 | 1.3 |
| Gray Treefrog | 37.9 | 1.9 |
| American Toad | 36.9 | 1.5 |
| N. Leopard Frog | 32.6 | 1.3 |
| Bullfrog | 26.6 | 1.3 |
| Chorus Frog | 25.3 | 1.7 |
| Wood Frog | 18.7 | 1.5 |
| Pickerel Frog | 2.4 | 1.1 |
| Fowler's Frog | 1.4 | 1.2 |
| Mink Frog | 1.3 | 1.2 |
| Blanchard's Cricket Frog | 0.9 | 1.2 |
| Cope's Gray Treefrog | 0.9 | 1.3 |

* MMP Survey stations monitored for multiple years considered as individual samples.

Frequency of occurrence and average Call Level Code for amphibian species detected inside Great Lakes basin MMP stations, 1995 through 1999. Average calling codes are based upon the three level call code standard for all MMP amphibian surveys; surveyors record Code 1 (little overlap among calls, numbers of individuals can be determined), Code 2 (some overlap, numbers can be estimated) or Code 3 (much overlap, too numerous to be estimated).
Source: Marsh Monitoring Program

sedimentation, contaminant and nutrient inputs, and invasion of non-native plants and animals.

**Acknowledgments**

Author: Russ Weeber, Bird Studies Canada, Port Rowen, ON.

The Marsh Monitoring Program is delivered by Bird Studies Canada in partnership with Environment Canada's Canadian Wildlife Service and with significant support from the U.S. Environmental Protection Agency's Great Lakes National Program Office and Lake Erie Team. The contributions of all Marsh Monitoring Program staff and volunteers are gratefully acknowledged.

## urtle Eggs

**Assessment:** Mixed

**Purpose**

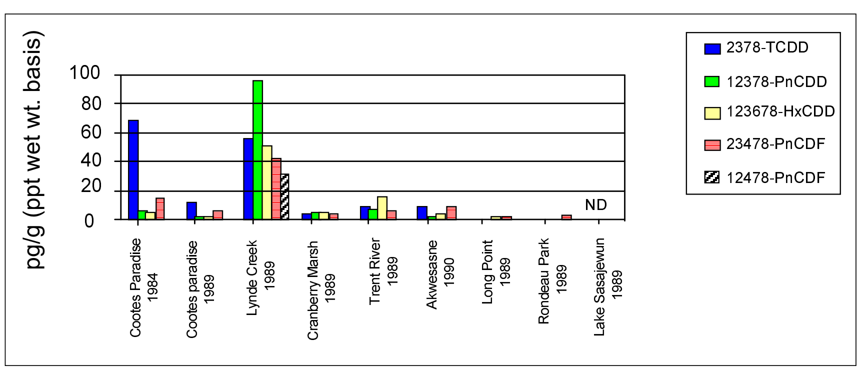
This indicator measures the concentrations of persistent contaminants in the eggs of common snapping turtles living in wetlands of the Great Lakes basin in order to provide an indirect measure of foodweb contamination and its effects on wetland wildlife.

**State of the Ecosystem**

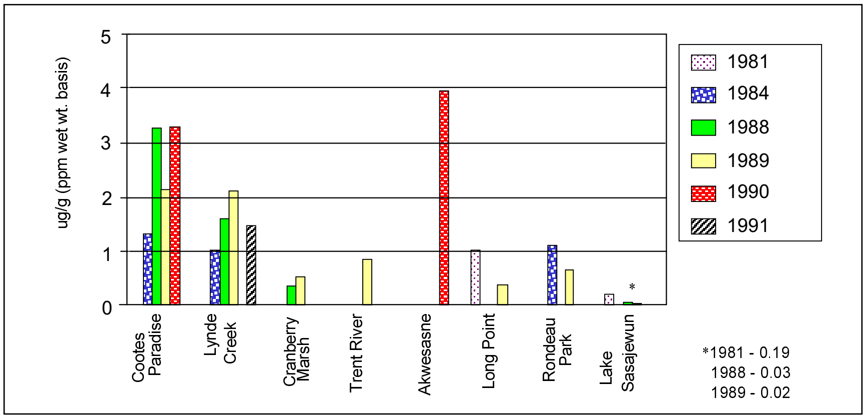
Snapping turtle eggs collected at two Lake Ontario sites (Cootes Paradise and Lynde Creek) had the highest polychlorinated dioxins (PCDD) concentrations (notably 2,3,7,8-TCDD) and number of detectable furans (PCDF). Eggs from Cranberry Marsh (Lake Ontario) and two Lake Erie sites (Long Point and Rondeau Provincial Park) had similar levels of PCBs and organochlorines. Eggs from Akwesasne (St. Lawrence River) contained the highest level of PCBs relative to all other sites.

Levels of PCBs and DDE (not shown) increased significantly from 1984 to 1990/91 in eggs from Cootes Paradise and Lynde Creek, but levels of PCDDs (including 2,3,7,8-TCDD) and PCDFs 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 all other sites studied.




Dioxin and furan concentrations (1984; 1989/90) in snapping turtle eggs at Canadian Great Lakes study sites.
Source: C. Bishop, Canadian Wildlife Service




Mean sum PCB concentrations (1981-1991) in snapping turtle eggs at Canadian Great Lakes study sites and one inland reference site.
Source: C. Bishop, Canadian Wildlife Service

**Future Pressures**

Snapping turtles in some Great Lakes locations will continue to be exposed to toxic chemicals through a diet of contaminated fish.

**Acknowledgments**

Author: Kim Hughes, Canadian Wildlife Service, Environment Canada, Downsview, ON.

Contributions from Christine Bishop, Canadian Wildlife Service, Environment Canada, R.J. Brooks, University of Guelph, Canadian Wildlife Service - National Wildlife Research Centre and Peggy Ng, York University.

## Wetland-Dependent Bird Diversity and Abundance

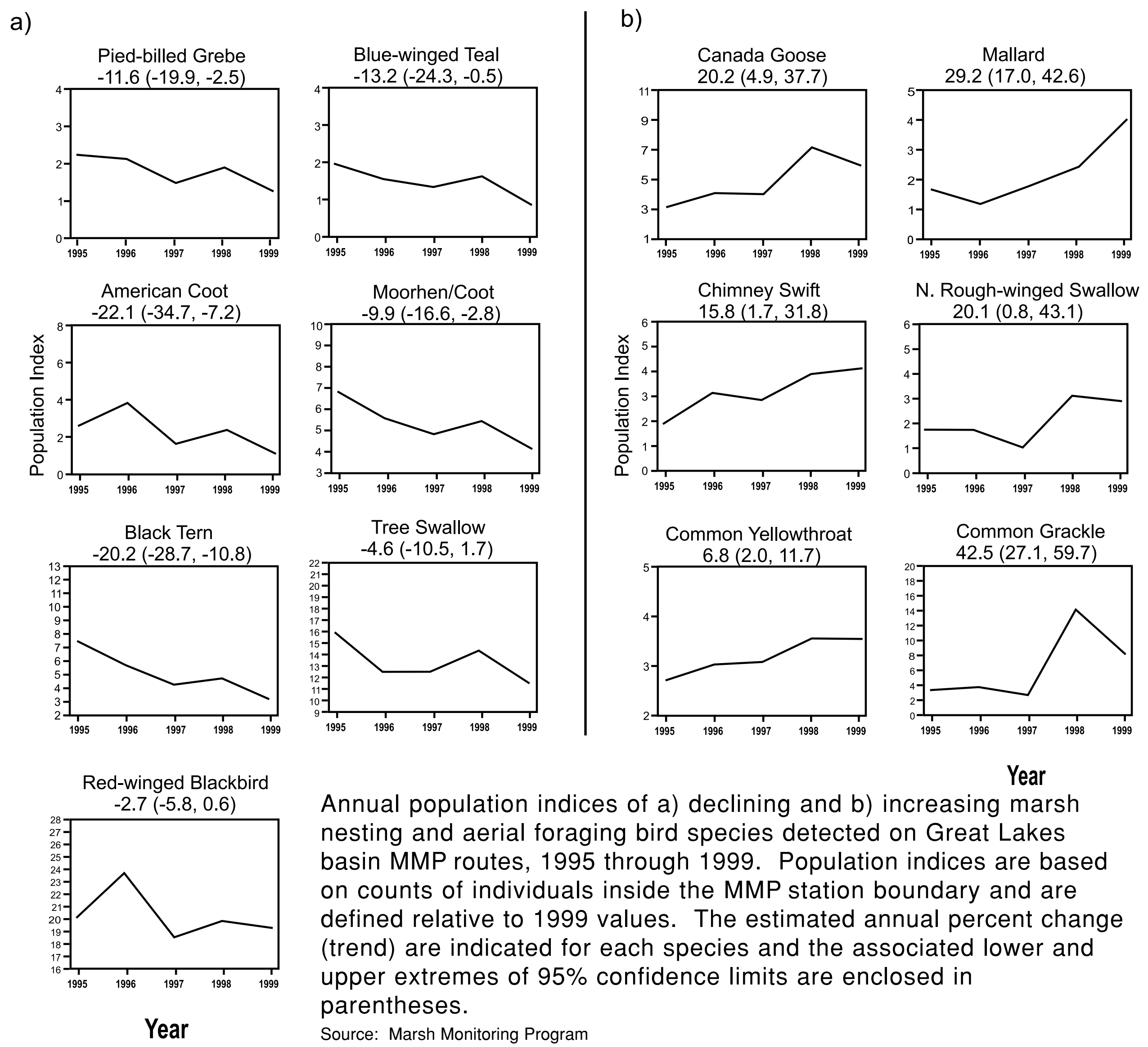
**Assessment:** Mixed, deteriorating

**Purpose**

Assessments of the diversity and abundance of wetland-dependent birds in the Great Lakes basin, combined with an analysis of habitat characteristics, are used to evaluate the health and function of wetlands.

**State of the Ecosystem**

Although results are still preliminary, from 1995 through 1999, 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 322 routes throughout the Great Lakes basin. Statistically significant basin-wide increases were observed for Canada Goose, Mallard, Chimney Swift, Northern Rough-winged Swallow, Common Yellowthroat and Common Grackle. Species with significant basin-wide declines were Pied-billed Grebe, Blue-winged Teal, American Coot, undifferentiated Common Moorhen/American Coot, and Black Tern. Each of the declining species depends upon wetlands for breeding, but because they use wetland habitats almost exclusively, the Pied-billed Grebe, American Coot, Common Moorhen, and Black Tern are particularly dependent on the availability of healthy wetlands.




Annual population indices of a) declining and b) increasing marsh nesting and aerial foraging bird species detected on Great Lakes basin MMP routes, 1995 through 1999. Population indices are based on counts of individuals inside the MMP station boundary and are defined relative to 1999 values. The estimated annual percent change (trend) are indicated for each species and the associated lower and upper extremes of 95% confidence limits are enclosed in parentheses.

Source: Marsh Monitoring Program

**Future Pressures**

Continuing loss and degradation of important breeding habitats through wetland loss, water level stabilization, sedimentation, contaminant and nutrient inputs, and the invasion of non-native plants and animals will continue putting pressure on these bird populations.

**Acknowledgments**

Author: Russ Weeber, Bird Studies Canada, Port Rowen, ON.

The Marsh Monitoring Program is delivered by Bird Studies in partnership with Environment Canada's Canadian Wildlife Service and with significant support from the U.S. Environmental Protection Agency's Great Lakes National Program Office and Lake Erie Team. The contributions of all Marsh Monitoring Program staff and volunteers are gratefully acknowledged.

## etland Area by Type

**Assessment:** Mixed, deteriorating

**Purpose**
The purpose of this indicator is to examine and better understand periodic changes in area of coastal wetland types, taking into account natural variations in areal extent and changes within wetlands.

**State of the Ecosystem**
Wetlands continue to be lost and degraded, yet the ability to track and determine the extent and rate of this loss in a standardized way is not yet feasible.

Adding up the area of individual wetlands from the Ontario Coastal Wetland Atlas will provide an initial estimate of the total Canadian Great Lakes coastal wetland area. This process is unlikely to be repeated, however, since it is labour intensive, expensive, and covers a very large geographic area.

Other methods to look at trends in coastal wetland area rely on remotely sensed data. For example, the U.S. Fish and Wildlife Service published the National Wetland Inventory (NWI) in 1982, based on the analysis of aerial photographs with ground-truth. The NWI includes delineated wetland types with updates to be prepared every 10 years. The first one was in 1990. Updates are based on a statistical sampling of wetlands, not on a full set of aerial photos. The NWI, however, does not specifically identify coastal wetlands.

Numerous research efforts are underway to assess the use of remote sensing technologies, and in some cases combine the results of satellite remote sensing, aerial photography and field work to document recent wetland loss. In the future, remote sensing will be used to provide an overview and facilitate a binational map of Great Lakes coastal wetlands as well as to establish a consistent methodology for tracking change and to facilitate faster updates in areas of high land-use change.

**Future Pressures**
Reductions in wetland area are continuing from filling, dredging and draining for conversion to other uses such as urban, agricultural, marina, and cottage development; shoreline modification; water level regulation; sediment and nutrient loading from watersheds; adjacent land use; non-native invasive species; and climate variability and change.

**Acknowledgments**
Authors: Lesley Dunn, Canadian Wildlife Service, Environment Canada, Downsview, ON and Laurie Maynard, Canadian Wildlife Service, Environment Canada, Guelph, ON.

Contributions from Doug Forder, Canadian Wildlife Service, Environment Canada, Duane Heaton, U.S. Environmental Protection Agency, Linda Mortsch, Meteorological Service of Canada, Environment Canada, Nancy Patterson, Canadian Wildlife Service, Environment Canada and Brian Potter, Ontario Ministry of Natural Resources.

## fects of Water Level Fluctuations

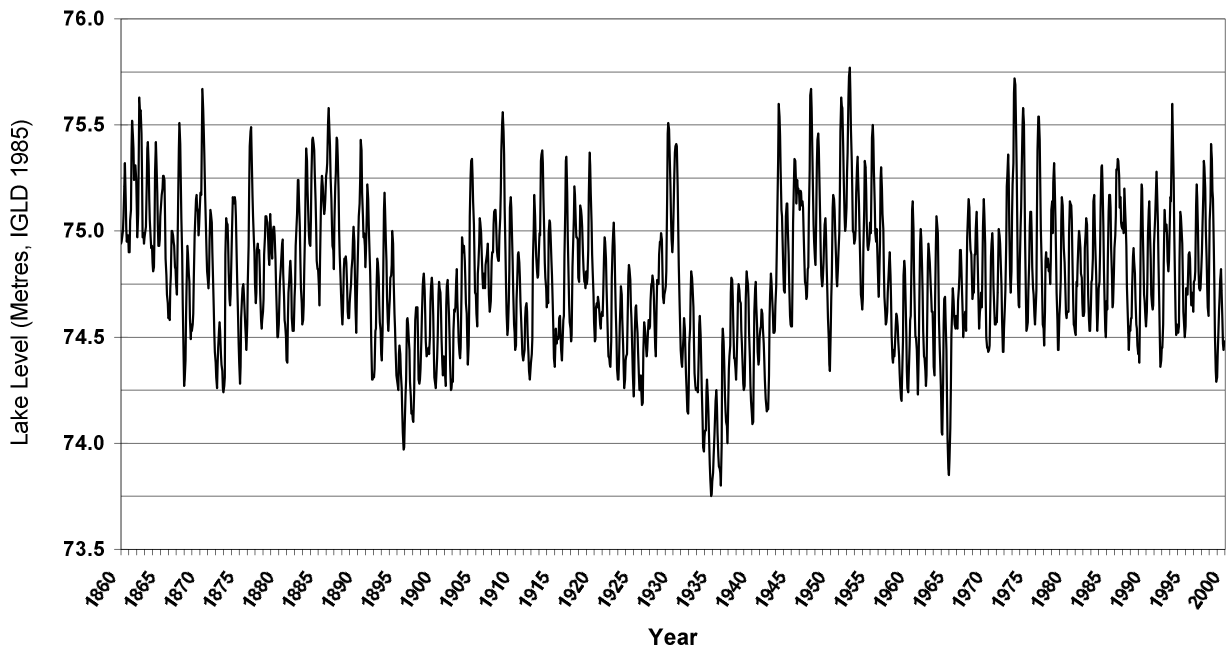
**Assessment:** Mixed, deteriorating

**Purpose**
The purpose of this indicator is to assess the lake 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.

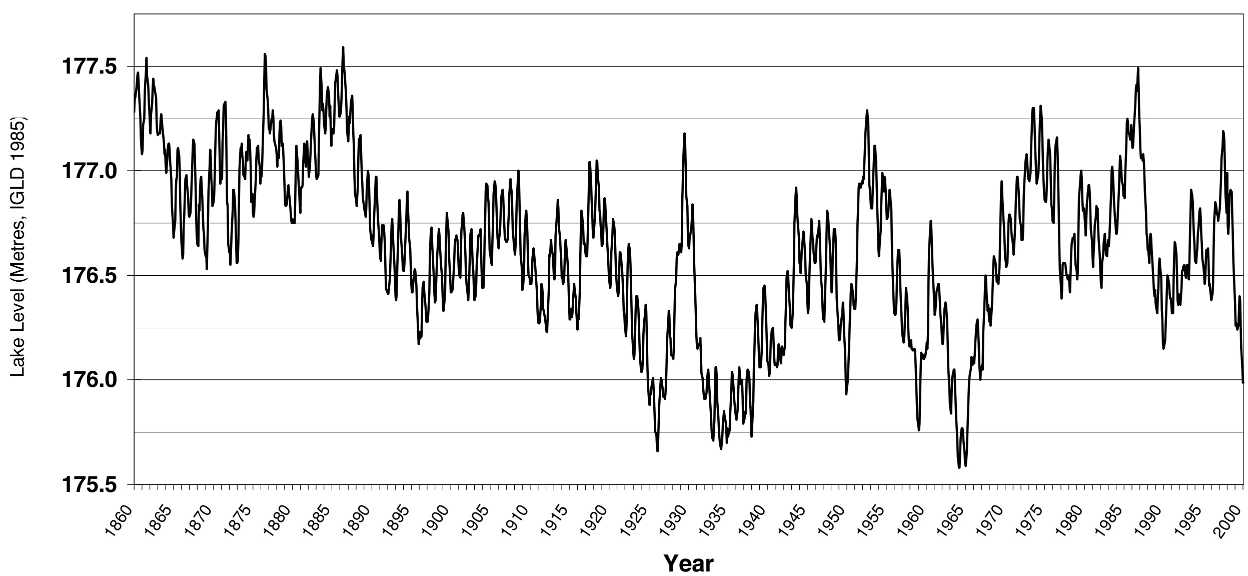
**State of the Ecosystem**
Quasi-periodic lake level fluctuations, both in period and amplitude, occur on an average of about 160 years, with sub-fluctuations of approximately 33 years. The levels in Lakes Michigan and Huron show the characteristic high and low water levels. Data for Lake Ontario show these fluctuations, but their amplitude has been reduced since the Lake level began to be regulated by various dams in 1959.

During periods of high water, there is a die-off of species that cannot tolerate long periods of increased depth of inundation. As the water levels recede, seeds buried in the sediments germinate and vegetate the newly exposed zone. During periods of low water, woody plants and emergents become established. This is the 'normal' relationship between wetlands and fluctuating water levels.

Under more stable water levels, such as in Lake Ontario, coastal wetlands occupy narrower zones along the Lakes and are considerably less diverse because dominant species such as cattails take over.




Lake Michigan-Huron Actual Levels.




Lake Ontario Actual Levels.

Actual water levels for Lakes Huron and Michigan (upper) and Lake Ontario (lower).

IGLD-International Great Lakes Datum. Zero for IGLD 1985 is Rimouski, Quebec, at the mouth of the St. Lawrence River. Water level elevations in the Great Lakes/St. Lawrence River system are measured above water level at this site.

Source: National Oceanic and Atmospheric Administration

**Future Pressures**

Future pressures include additional withdrawals or diversions of water from the Lakes; additional regulation or smoothing of the high and low water levels; and global climate variability and change.

**Acknowledgments**

Author: Duane Heaton, U.S. Environmental Protection Agency, Chicago, IL.

Contributions from Douglas A. Wilcox, U.S. Geological Survey, Biological Resources Division, Todd A. Thompson, Indiana Geological Survey, and Steve J. Baedke, James Madison University.

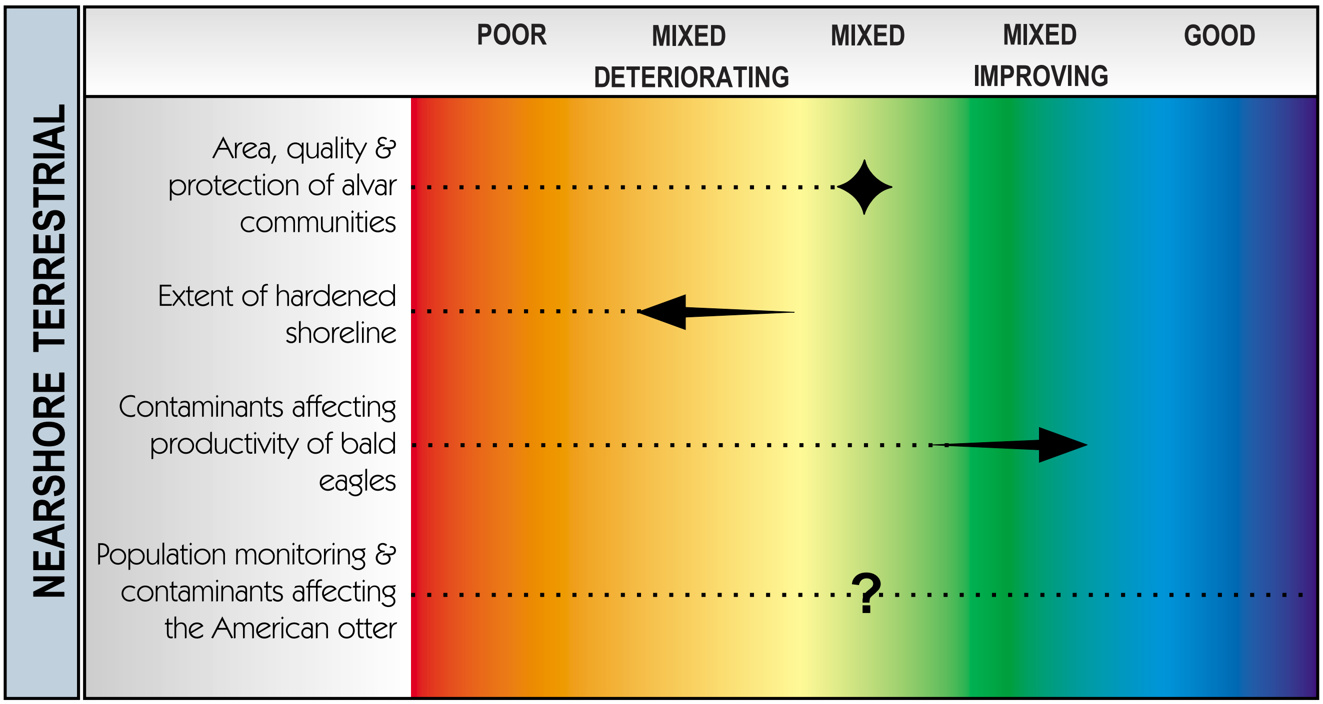



Time series at Fish Point (east shore of Saginaw Bay, Lake Huron) from 1988 to 1993 showing the effects of fluctuating water levels on a coastal wetland.

Photo credits: Douglas A. Wilcox, U.S. Geological Survey

## 3.3 Nearshore Terrestrial

### Nearshore Terrestrial Indicators - Assessment at a Glance



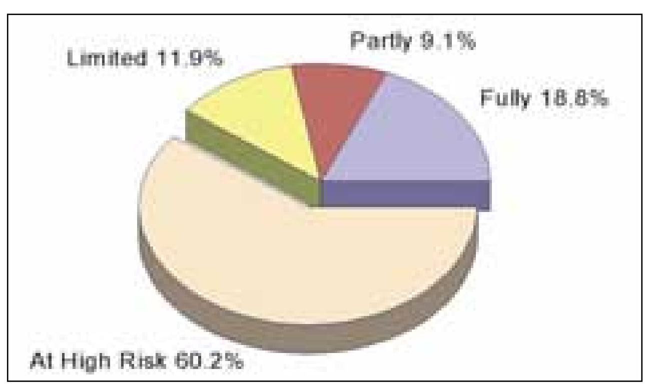

### Area, Quality and Protection of Alvar Communities

**Assessment:** Mixed

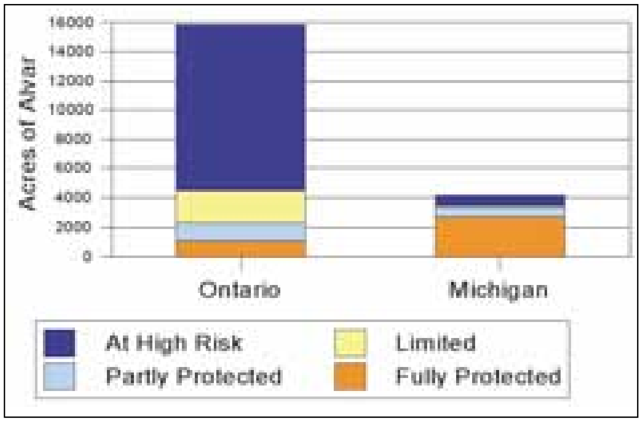
**Purpose**
This indicator assesses the status of one of the 12 special lakeshore communities identified within the nearshore terrestrial area. Alvar communities are naturally open habitats occurring on flat limestone bedrock.

**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.



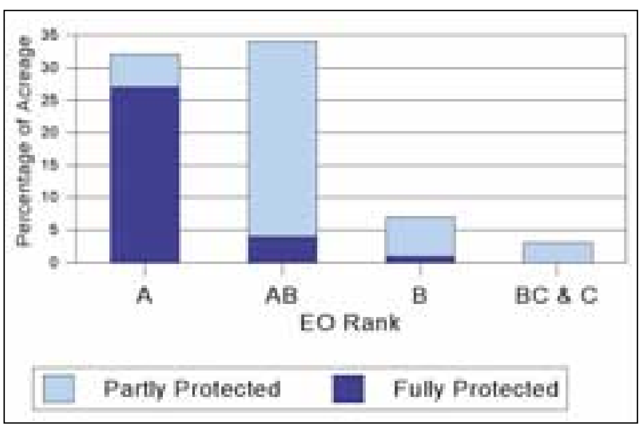

Protection status 2000. Nearshore alvar acreage.
Source: Ron Reid, Bobolink Enterprises




Comparison of acreage protected. Nearshore alvars: Ontario and Michigan.

Source: Ron Reid, Bobolink Enterprises

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 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.




Protection of high quality alvars.

Source: Ron Reid, Bobolink Enterprises

**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.

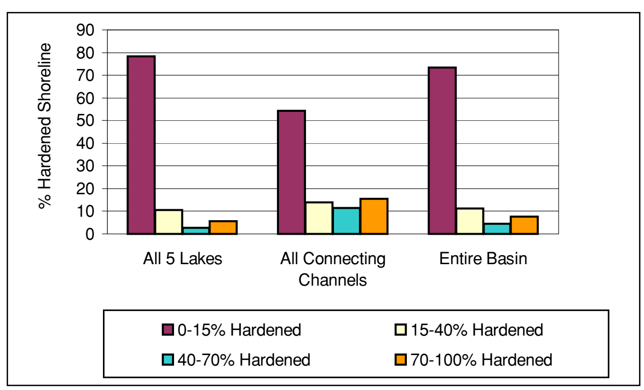
## **Assessment:** Mixed, deteriorating

**Purpose**

This indicator assesses the extent of hardened shoreline through the construction of sheet piling, rip rap, or other erosion control structures. Shoreline hardening not only directly destroys natural features, but also disrupts biological communities that are dependent upon the transport of shoreline sediment by lake currents. Hardening also destroys inshore habitat for fish, birds and other biota.

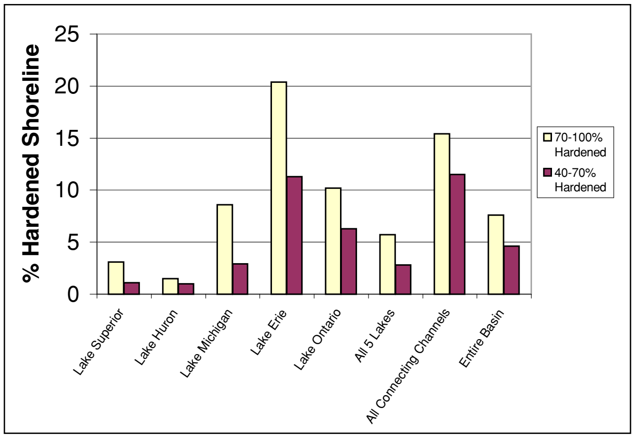
**State of the Ecosystem**

The St. Clair, Detroit, and Niagara Rivers have a higher percentage of their shorelines hardened than anywhere else in the basin. Of the Lakes




Shoreline hardening in the Great Lakes (compiled from 1979 data for the state of Michigan and 1987-1989 data for rest of the basin).

Source: Environment Canada and National Oceanic and Atmospheric Administration




Shoreline hardening by lake (compiled from 1979 data for the state of Michigan and 1987-1989 data for rest of the basin).

Source: Environment Canada and National Oceanic and Atmospheric Administration

themselves, Lake Erie has the highest percentage of its shoreline hardened, and Lakes Huron and Superior have the lowest.

Along about 22 kilometres of the Canadian side of the St. Clair River, an additional 5.5 kilometres (32%) of the shoreline had been hardened over the 8-year period from 1991 to 1999. This rate of hardening is not representative of the overall basin, however. The St. Clair River is a narrow shipping channel with high volumes of Great Lakes traffic, and many property owners are hardening the shoreline to reduce the impacts of erosion.

**Future Pressures**

Shoreline hardening can be considered a permanent feature and additional stretches of shoreline will be hardened, especially during periods of high lake levels. This additional hardening will, in turn, starve the downcurrent areas of sediment to replenish the eroded materials and causes further erosion and further incentive for additional hardening.

**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.

## fecting

**Assessment:** Mixed, improving

**Purpose**

This indicator assesses the number of fledged young, number of developmental deformities, and the concentrations of organic contaminants 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**

The concentrations of p,p-DDE, total PCBs, and mercury in blood plasma and feathers of nestling bald eagles in Michigan are either stable or declining from concentrations observed in the late 1980s and early 1990s. The majority (>95%) of eggs tested, however, exhibited contaminant concentrations greater than No Observed Adverse Effects Concentrations (NOAECs) for PCBs and p,p'-DDE, and the number of observed developmental deformities has increased over time.


Approximate nesting locations of bald eagles along the Great Lakes shorelines, 2000.

Source: W. Bowerman, Clemson University, Lake Erie and Lake Superior LaMPs, and for Lake Ontario, Peter Nye, NY Department of Environmental Conservation

The number of nestling eagles fledged from nests along the shorelines of the Great Lakes has steadily increased from six in 1977 to over 200 in 2000, including the first record of a nesting pair along the shoreline of Lake Ontario.

**Future Pressures**

Pressures on bald eagles include continued exposure, through food chain mechanisms, to environmental pollutants; human related disturbances near nest sites; food availability; loss of habitat due to development; and the loss of protection after delisting from the U.S. Endangered Species list. For those eagles nesting above barrier dams, there is the potential for fish passage of contaminated Great Lakes fishes.

**Acknowledgments**

Authors: William Bowerman, Clemson University, David Best, U.S. Fish & Wildlife Service, and Michael Gilbertson, International Joint Commission.

## fecting the American Otter

**Assessment:** Insufficient data to assess

**Purpose**

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

**State of the Ecosystem**

General otter population indices derived from state and provincial data indicate that primary areas of suppression still exist in western Lake Ontario watersheds, southern Lake Huron watersheds, lower Lake Michigan and most Lake Erie watersheds. Data suggest that otter are almost absent in western Lake Ontario. Most coastal shoreline areas have more suppressed populations than interior zones and Great Lakes drainage populations.

Areas of otter population suppression are directly related to human population centres and subsequent habitat loss.

**Future Pressures**

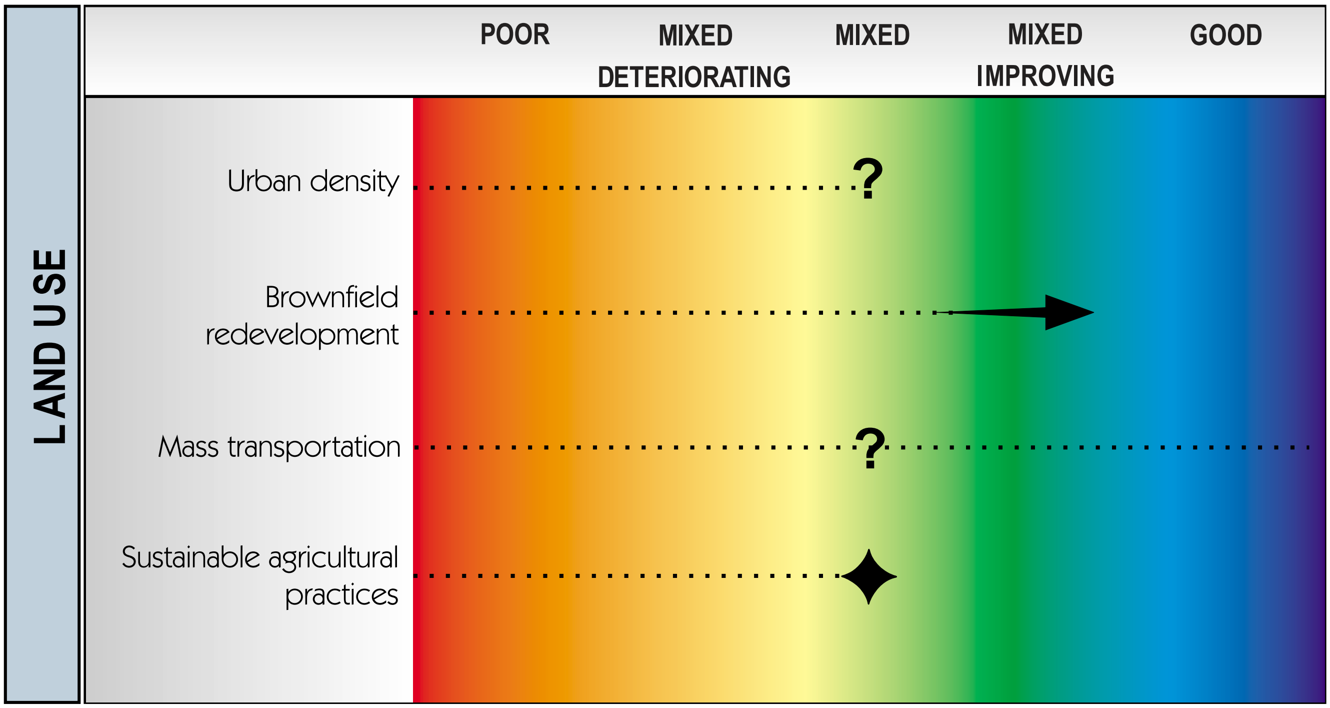
Otter will continue to be under pressure from organic and heavy metal concentrations in the food chain, and anthropogenic alterations of river and lake habitats.

**Acknowledgments**

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

# 3.4 Land Use

## Land Use Indicators - Assessment at a Glance




## Urban Density

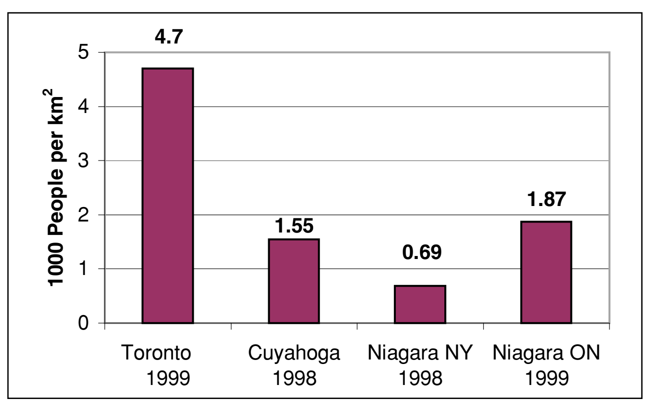
**Assessment:** Unable to assess status until targets are determined

**Purpose**

This indicator measures human population density and indirectly measures the degree of inefficient land use and urban sprawl for communities in the Great Lakes basin. The number of people that inhabit a community relative to its size is an indicator of the economic efficiency of that community based on the existence of 'economies of scale' associated with high density development.

**State of the Ecosystem**

There are marked differences around the Great Lakes basin in communities' urban densities. Initial research compared the larger more established urban cities of Toronto, Ontario and Cuyahoga County, Ohio (which includes Cleveland) and the two smaller communities of the Regional Municipality of Niagara, Ontario and Niagara County, New York. Factors such as ongoing 'rust belt' U.S. population




Urban densities in four Great Lakes urban communities.

Source: Rivers Consulting and J. Barr Consulting declines may be partly responsible for the statistical differences in urban densities.

Trends over the last ten years indicate that population densities are increasing in both of the Canadian communities sampled and are stable to declining in the U.S. communities.

**Future Pressures**

Continued urban sprawl and low density development throughout the basin represent significant pressures.

**Acknowledgments**

Authors: Ray River, Rivers Consulting, Campbellville, ON, and John Barr, Burlington, ON.

## Assessment: Mixed, improving

**Purpose**

This indicator assesses the acreage of redeveloped brownfields, and it is used to evaluate over time the rate at which society rehabilitates and reuses former developed sites that have been degraded or abandoned.

**State of the Ecosystem**

Information on acres of brownfields remediated from Illinois, Minnesota, New York, and Pennsylvania indicates that a total of 28,789 acres of brownfields have been remediated in these jurisdictions alone. Available data from six Great Lakes states indicate that more than 8,662 brownfield sites have participated in brownfields cleanup programs. Though there are inconsistent and inadequate data on acres of brownfields remediated and/or redeveloped, available data indicate that both brownfields cleanup and redevelopment efforts have risen dramatically since the mid 1990s. This is due to the new wave of risk-based cleanup standards and widespread use of state liability relief mechanisms that allow private parties to redevelop, buy or sell property without being held liable for contamination they did not cause. Data also indicate that the majority of cleanups in Great Lakes states and provinces are occurring in older urbanized areas, many of which are located on the Great Lakes and in the basin. Based on this information, the state of brownfields redevelopment is good and improving.

Brownfield site in Detroit, Michigan, 1998.

Photo Credit: Victoria Pebbles, Great Lakes Commission

**Future Pressures**

Continued pressures include: lack of long-term monitoring and enforcement of exposure controls (examples of exposure control include capping a site with clean soil or restricting the use of ground water); cleanup standards based on risks to human health that may not be appropriate for habitat creation/enhancement; the potential for contaminated groundwater to interface with surface waters and cause degradation of surface waters; and policies that encourage new development to occur outside already developed areas over urban brownfields.

**Acknowledgments**

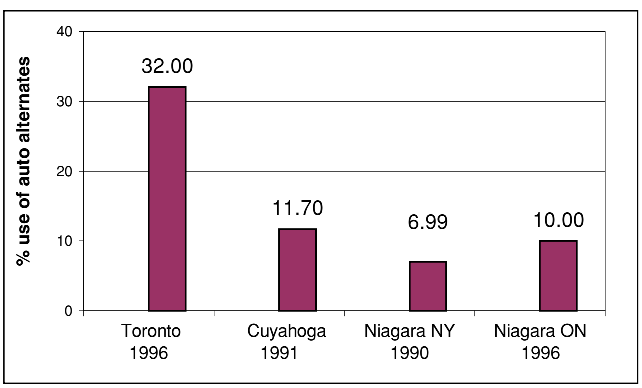
Author: Victoria Pebbles, Great Lakes Commission, Ann Arbor, MI.

## ransportation

**Assessment:** Unable to assess status until targets are determined

**Purpose**
This indicator measures the percentage of daily commuters that use public transportation or other alternatives to the private car. It indirectly measures the stress to the Great Lakes ecosystem caused by the use of the private motor vehicle and its resulting high resource utilization and creation of pollution.

**State of the Ecosystem**
There are marked differences amongst four sample Great Lakes basin communities in automobile usage for commuting. Initial research showed that there is a direct relationship between public transportation and the degree of urban density. Higher usage of transportation alternatives occurs within the larger more established urban cities of Toronto, Ontario and Cuyahoga County, Ohio (which includes Cleveland) than within the more lightly populated and smaller communities of the Regional Municipality of Niagara, Ontario and Niagara County, New York. This relationship was pronounced in Toronto where higher density also facilitated greater use of bicycling and walking amongst urban commuters.




Percentage of commuters using alternatives to automobiles in selected communities.

Source: Rivers Consulting and J. Barr Consulting

**Future Pressures**
Significant pressures arguing for more mass transportation are population growth combined with urban sprawl.

**Acknowledgments**

Authors: Ray Rivers, Rivers Consulting, Campbellville, ON, and John Barr, Burlington, ON.

**Assessment:** Mixed

**Purpose**
This indicator assesses the number of Environmental and Conservation farm plans and environmentally friendly agricultural practices in place, such as integrated pest management to reduce the potential adverse impacts of pesticides, and conservation tillage and other soil preservation practices to reduce energy consumption, prevent ground and surface water contamination, and achieve sustainable natural resources.

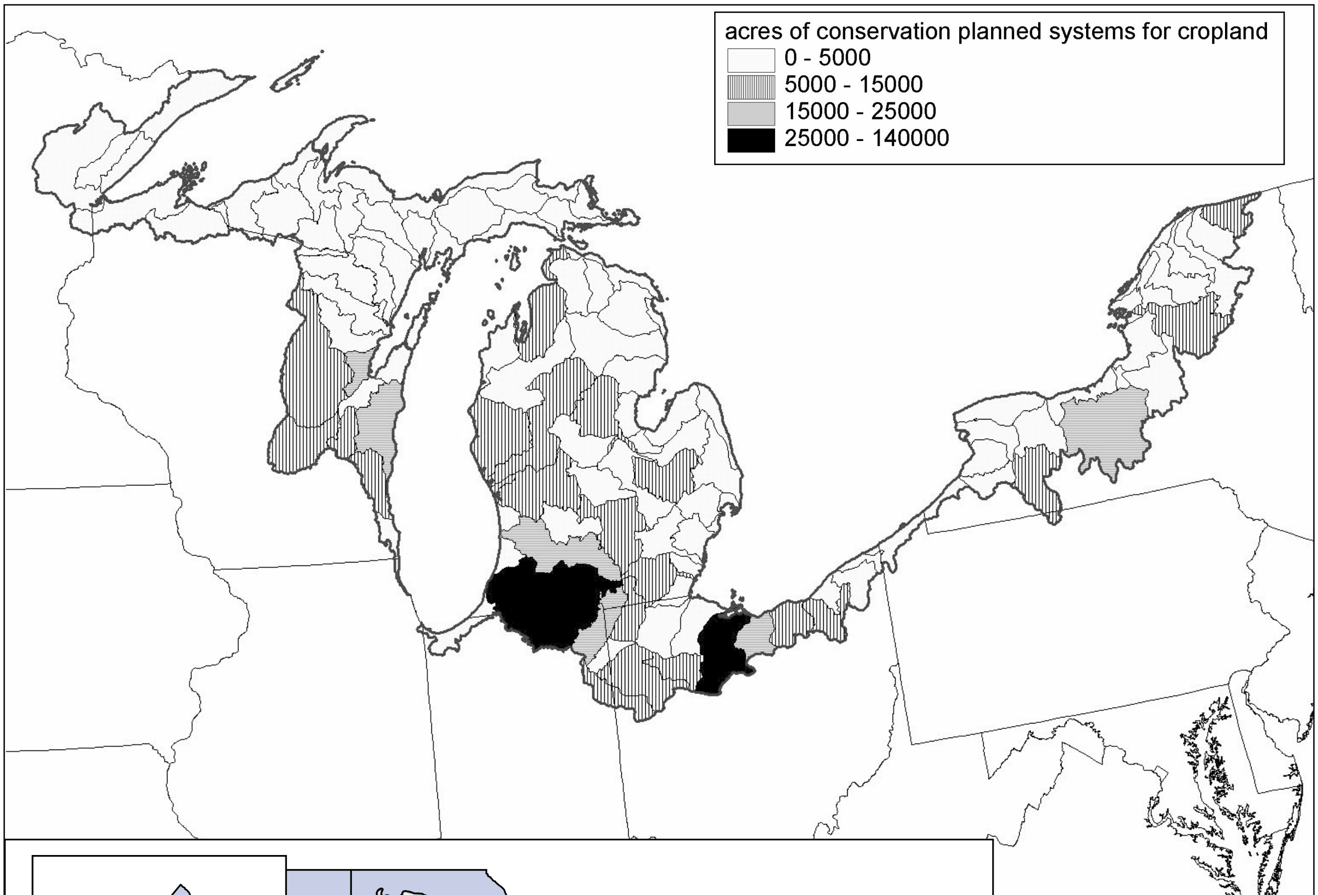
**State of the Ecosystem**
Agriculture accounts for 35% of the land area of the Great Lakes basin and dominates the southern portion of the basin. In the past, excessive tillage and intensive crop rotations led to soil erosion and the resulting sedimentation of major tributaries. Agriculture is a major user of pesticides with an annual use of 26,000 tons. These practices led to a decline of soil organic matter. Recently there has been increasing cooperation between government and the farm community on Great Lakes water quality management programs. The adoption of more environmentally responsible practices has helped to replenish carbon in the soils back to 60% of turn-of-the-century levels.

Both the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and the USDA's Natural Resources Conservation Service (NRCS) provide conservation planning advice, technical assistance and incentives to farm clients and rural landowners. On a voluntary basis clients develop and implement conservation plans to protect, conserve, and enhance natural resources that harmonize productivity, business objectives and the environment.

**Future Pressures**
Sustainable agricultural practices will be compromised by increasing farm size and concentration of livestock; changing land use and development pressures (including higher taxes), traffic congestion, flooding and pollution.

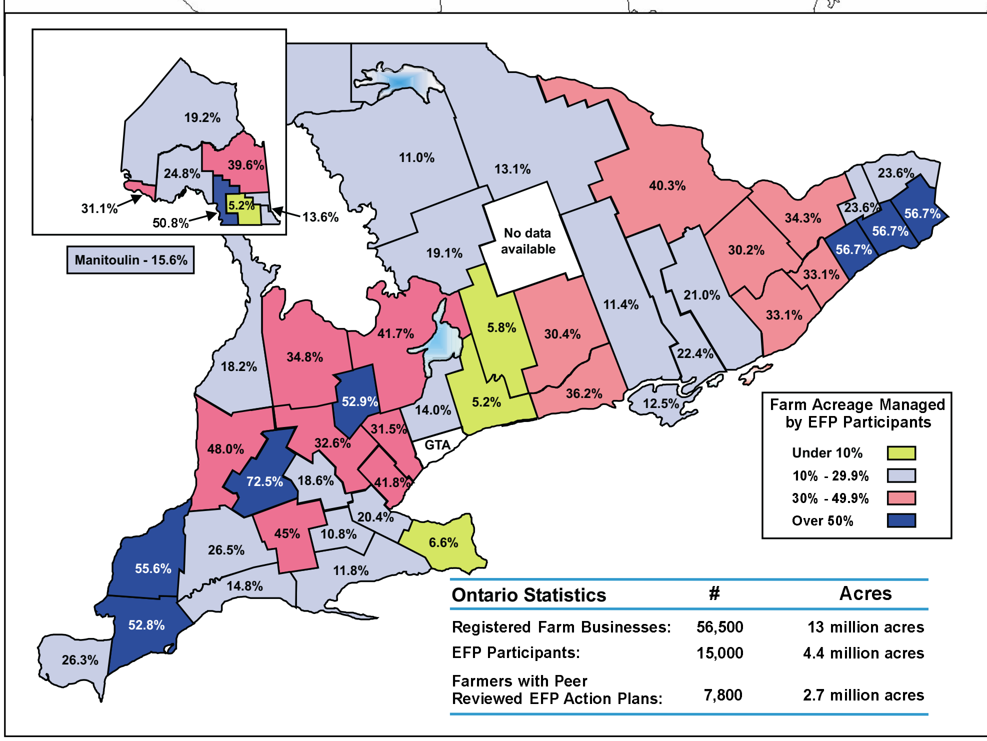
**Acknowledgments**

Authors: Roger Nanney, U.S. Natural Resources Conservation Service, Chicago, IL, and Peter Roberts, Ontario Ministry of Agriculture, Food and Rural Affairs, Guelph, ON.




Annual U.S. conservation planned systems for 2000.

Source: U.S. Department of Agriculture, NRCS, Performance and Results Measurement System



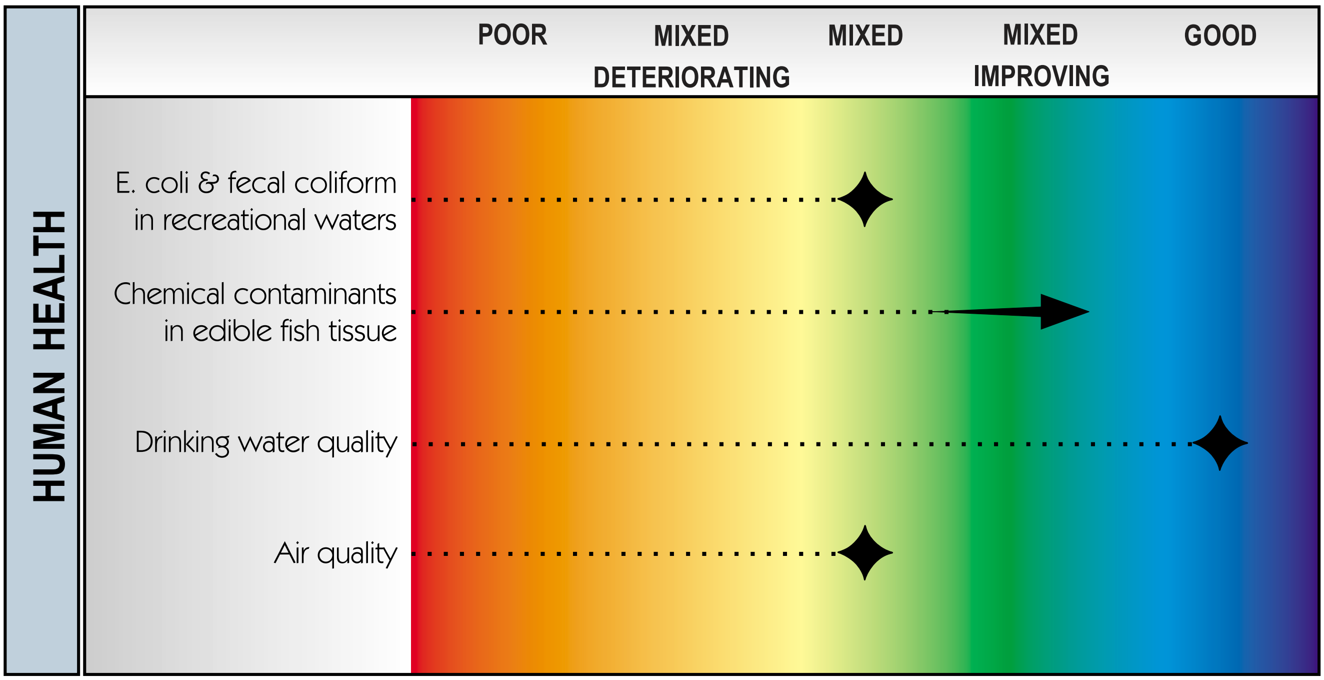

| Ontario Statistics | # | Acres |
|---|---|---|
| Registered Farm Businesses: | 56,500 | 13 million acres |
| EFP Participants: | 15,000 | 4.4 million acres |
| Farmers with Peer Reviewed EFP Action Plans: | 7,800 | 2.7 million acres |

Ontario Environmental Farm Plan (EFP).

Source: Ontario Soil and Crop Improvement Association, April 1999, 1997 Ontario farm registration database, 1996 Census of Agriculture

# 3.5 Human Health

## Human Health Indicators - Assessment at a Glance




## *E. coli* and Fecal Coliform in Recreational Waters

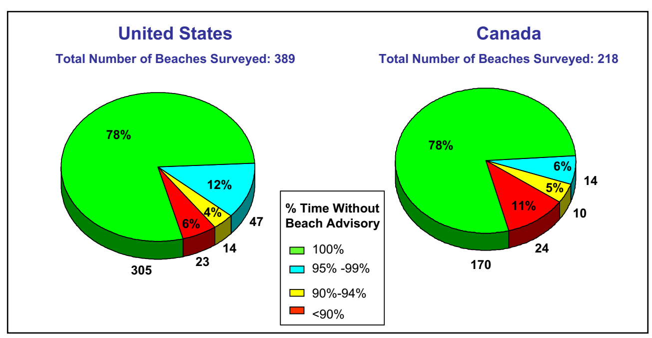
**Assessment:** Mixed

**Purpose**

This indicator assesses *E. coli* and fecal coliform contamination levels in nearshore recreational waters, acting as a surrogate indicator for other pathogen types, and it is used to infer potential harm to human health through body contact with nearshore recreational waters.

**State of the Ecosystem**

Survey reports of U.S. beach advisories during the 1998 swimming season (June, July, August) show that 78% of the reporting beaches were open for the entire 1998 season. Results were similar for Canadian beaches where 78% of the reporting beaches were open the entire season.

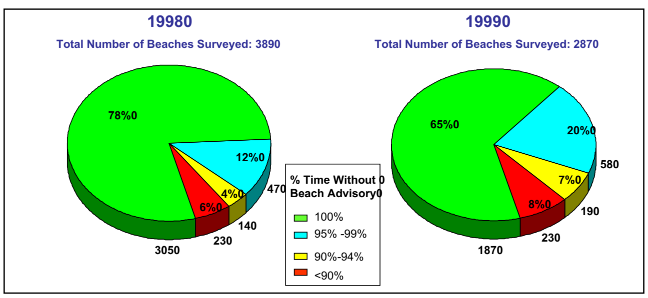



Comparison of U.S. and Canadian beach advisories for Great Lakes beaches, 1998.

Source: U.S. Environmental Protection Agency Beach Watch Program, National Health Protection Survey of Beaches for Swimming (1998) and Ontario Ministry of Environment

Survey reports of U.S. beach closings or advisories during the 1999 season show that 65% of the reporting beaches were open for the entire 1999 season. Several factors may have influenced the apparent increase in percentage of beach closings in 1999 compared with 1998:

- Fewer beach managers responded to survey questionnaires in 1999, and of those beaches that were reported, not all had been included in the 1998 data;
- More beach managers were using *E. coli* testing in 1999 than in 1998. *E. coli* is a more sensitive indicator of public health risks for swimmers, and it gives more consistent results. U.S. jurisdictions have begun to adopt uniform testing procedures for *E. coli* in the water at swimming beaches. This is an improvement over past methods and will provide more accurate information about potential risks to human health from swimming. While the actual water quality near beaches may not have changed, this new method may result in more beach advisories in the future; and
- A different accounting for the number of beach advisory days was used in 1999. For example, a two day episode of elevated bacterial levels in 1998 would have counted as one beach advisory.




U.S. beach advisories for Great Lakes beaches, 1998 vs. 1999.

Source: U.S. Environmental Protection Agency Beach Watch Program, National Health Protection Survey of Beaches for Swimming (1998)

**Future Pressures**

Population growth causing both increased demands made on sewage treatment plant capacities and the probability of release of untreated effluent, as well as more private treatment systems, especially in resort/vacation areas, may cause an increase of undetected releases of inadequately treated waste.

**Acknowledgments**

The following personnel contributed data, analysis, or reporting expertise to this indicator:

David Rockwell, Paul Bertram, and Wade Jacobson (SEE Program), U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, Illinois. Richard Whitman, U.S. Geological Survey, Lake Michigan Ecological Research Station, Porter, Indiana. Marcia Jimenez, City of Chicago, Chicago, Illinois. Duncan Boyd and Mary Wilson, Ontario Ministry of Environment, Environmental Monitoring and Reporting Branch, Toronto, Ontario. Peter Gauthier, City of Toronto, Environmental Health Services, Toronto, Ontario.

## Chemical Contaminants in Edible Fish Tissue

**Assessment:** Mixed, improving

**Purpose**

This indicator assesses the concentration of persistent, bioaccumulating, 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 applied to historical data to track trends in fish consumption advice.

**State of the Ecosystem**

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 safe to eat. Advice from these agencies to limit consumption of fish is related to levels of PCBs, mercury, chlordane, dioxin, and toxaphene in the fish, but vary by lake.

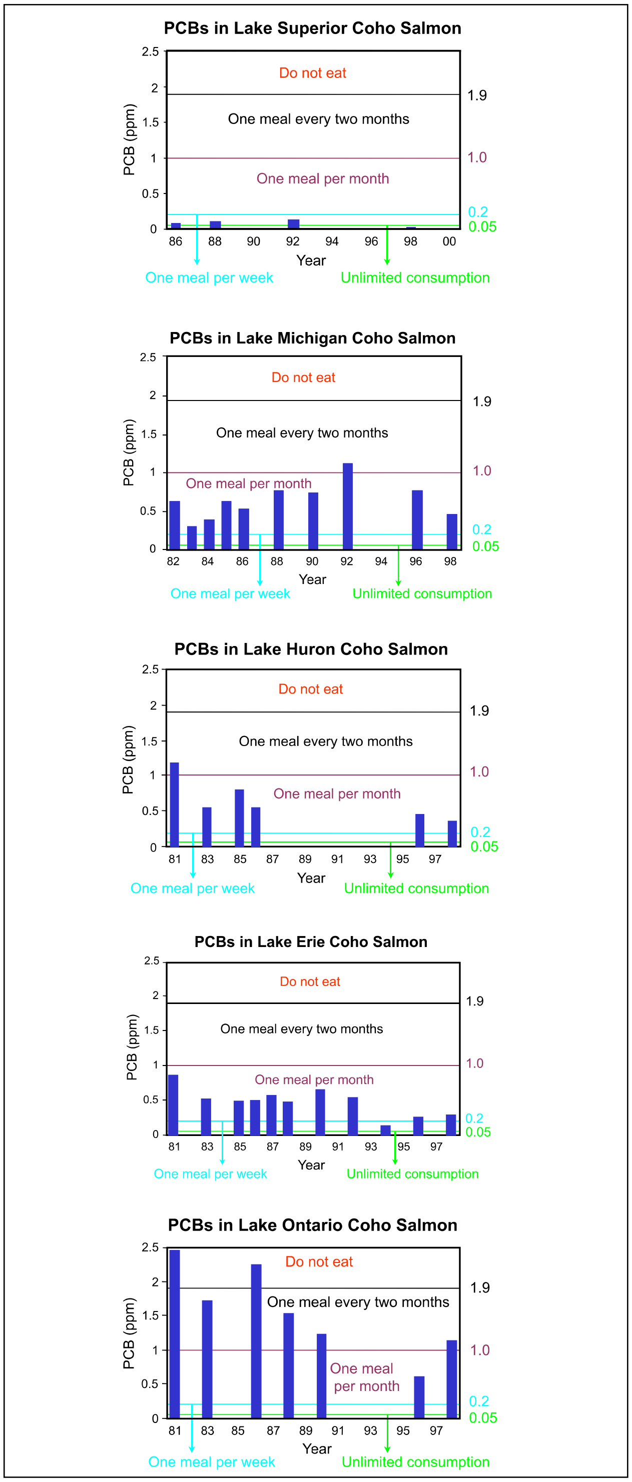
The accompanying figures illustrate the results of applying a uniform fish advisory protocol to historical data on PCBs in coho salmon fillets. The resulting advisories do not necessarily reflect actual advisories issued in each lake basin.

**Future Pressures**

Fish consumption advisories will still be required because of organochlorine contaminants, although these are generally decreasing. Mercury, the health effects of multiple contaminants, and endocrine disruptors are also of concern.

**Acknowledgments**

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




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

## ater Quality

**Assessment:** Good

**Purpose**

This indicator evaluates the chemical and microbiological 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, however this report focuses mainly on raw water from the Great Lakes proper.

At present, data from 22 sites around the basin have been assessed. The parameters used include both microbiological and chemical contaminants in raw water. Taste and odour, however, are most appropriately measured in treated water. The chemical parameters chosen were atrazine, nitrate and nitrite. These chemicals are seasonal and flow dependent. While minimal levels of atrazine, nitrate and nitrite were detected in raw water, monthly averages and maximums fell below the federal regulations for treated water. However, it should be noted that although atrazine seasonally enters the lakes by way of tributaries, this pattern was not detected at the 22 intakes included here.

Turbidity was chosen as a parameter for its correlation with potential microbial problems. High turbidity can interfere with disinfection and provide a medium for microbial growth. Turbidity values vary depending on season, location and lake. There are no raw water maximum levels for turbidity. However, by sampling raw water turbidity levels, the treatment plants can adjust treatment for optimal removal of microbial contaminants.

The level of organic matter can be determined by examining Total Organic Carbon (TOC) or Total Dissolved Organic Carbon (DOC). The DOC concentrations in raw water at the Canadian sites were fairly low, as was TOC at the majority of U.S. sites.

Taste and odour is a complex indicator. While it is an extremely important indicator to consumers, it is


U.S. and Canadian water treatment plants used in this report.

also difficult to quantitatively measure. Not all of the chosen water treatment sites had taste and odour data readily available. This indicator was evaluated for August 1999 at the six sites where data were available. Testing is done in August, since increased odour problems are usually associated with increased water temperatures. There were minimal problems with taste and odour at the six water treatment facilities that reported this parameter.

The microbiological indicators suggested are total coliform, *Escherischia coli*, *Giardia lambalia*, and *Cryptosporidium parvum*. The methods of analyzing water for *Giardia lambalia* and *Cryptosporidium parvum* are not the most reliable at this time, but it is suggested that these remain indicators as better methods become available. *Escherischia coli* is only tested when tap water tests positive for total coliform. Total coliform is probably the best choice for a microbial indicator at this time because it is the most uniformly tested. It is a required test in the U.S. and Canada. At the U.S. sites there have been no total coliform exceedances for the last ten years. While the total coliform data were available for the Canadian sites, there presently is no user-friendly method for exceedance interpretation.

The health of the Great Lakes, as determined by these drinking water parameters at these 22 sites, is good. Chemical contaminants are consistently tested to be at minimal levels even prior to treatment. Additionally, violations of these chemical and microbial parameters are extremely rare. The risk of human exposure to contaminants is low. The quality of drinking water as it leaves the water treatment plants meets standards. The quality of water delivered, however, can vary due to the possibility of contaminants entering the distribution system.

**Future Pressures**

Pressures that could compromise the quality of drinking water include land use and agricultural runoff; increases in both algal presence and water temperatures; byproducts of the drinking water disinfection process; and aging distribution systems.

**Acknowledgments**

This report was assembled by Molly Madden (Environmental Careers Organization), with the assistance of Rod Holme (American Water Works Association), Pat Lachmaniuk (Ontario Ministry of Environment), Tom Murphy (U.S. Environmental Protection Agency, Region 5), and Paul Bertram (U.S. Environmental Protection Agency, GLNPO). Additional thanks are due to the water treatment plant operators and managers who submitted the requested data.

**Assessment:** Mixed

**Purpose**
This indicator assesses the air quality in the Great Lakes ecosystem, and it is used to infer the potential impact of air quality on human health in the Great Lakes basin.

**State of the Ecosystem**
Overall, 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.

The pollutants have been divided into urban (or local) and regional pollutants for this report. Mention of the U.S. or Canada in this discussion refers to the respective portions of the Great Lakes basin. Latest published air quality data are for 1997 (Canada - Ontario) and 1999 (U.S.).

Urban/local pollutants include carbon monoxide (CO), nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$), lead, total reduced sulphur (TRS) and particulate matter. In general, there has been significant progress with urban/local pollutants over the past decade or more, though somewhat less in recent years, with a few remaining problem districts. For example, in Canada average ambient $NO_2$ levels have remained relatively constant through the 1990s, however the only year without exceedances of the ambient criteria was in 1997. In the U.S, for both $SO_2$ and particulate matter (with diameter of 10 microns or less), there are six regions that do not meet ambient criteria. Emissions in Canada of $SO_2$ have increased slightly in the last two years of the period and ambient levels have only shown a slight decrease in the 1990s.

For regional pollutants, transport is a significant issue, from hundreds of kilometres to the scale of the globe. Formation from other pollutants, both natural and man-made, can also be important. There are still short periods each year during which regional pollutants (primarily ozone and fine particulates and related pollutants - collectively called smog) reach levels of concern, essentially in southern and eastern portions of the basin. Regional pollutants include ground level ozone ($O_3$), fine particulate matter, and air toxics. Ozone is a problem pollutant over broad areas of the Great Lakes basin (except Lake Superior). Local circulations around the Great Lakes can exacerbate the problem: high levels are found near Lakes Huron and Erie, even in areas such as in provincial parks that are well removed from local industry, and western Michigan is strongly impacted by transport across Lake Michigan from Chicago. Fine particulate matter (diameter 2.5 microns or less) is a health concern as it can penetrate deeply into the lung. In Canada, available data indicate that many locations in Southern Ontario will exceed the recently endorsed standard of $30mg/m^3$ (24-hour average). In the U.S., there are not enough years of data to determine trends, but it appears that there may be many areas which do not attain the new U.S. standard. Air toxics of interest include those that have potential to harm human health (e.g. cancer), based on the toxicity and likelihood for exposure. Some ambient trends have been found: in the U.S. concentrations of benzene and toluene have shown significant decreases from 1993-1998, notably in the Lake Michigan region. Styrene has also shown a significant decrease (1996-1998).

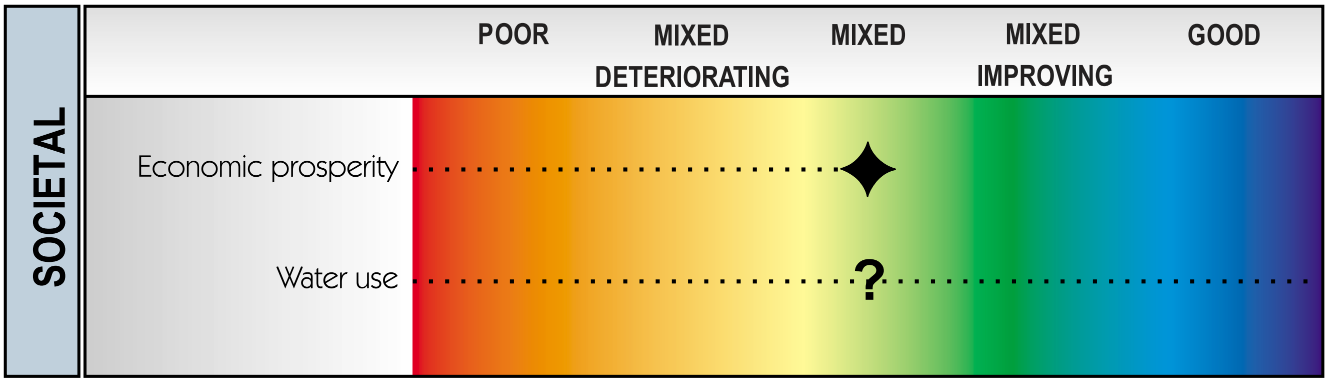
**Future Pressures**
Continued population growth and associated urban sprawl are threatening to offset emission reduction efforts and better control technologies, both through increased car-travel and energy consumption. Climate change may affect the frequency of weather conditions leading to high ambient concentrations of many pollutants. Evidence exists of changes to the atmosphere as a whole. Average ground-level ozone concentrations may be increasing on a global scale.

Continuing health research is both broadening the number of toxics of potential concern, and producing evidence that some existing standards should be reconsidered. There is epidemiologic evidence of health effects from ozone or fine particulates at or below levels previously considered to be background or "natural" levels.

**Acknowledgments**
Authors: Fred Conway, Environment Canada, Meteorological Services of Canada, Downsview, ON and Joseph Chung, U.S. Environmental Protection Agency, Air Division, Chicago, IL.

## 3.6 Societal

### Societal Indicators - Assessment at a Glance




### Economic Prosperity

**Assessment:** Mixed

**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. During periods of low unemployment (i.e. economic well-being), public support for environmental initiatives by government agencies and elected officials may be increased.

**State of the Ecosystem**

By most measures, the binational Great Lakes regional economy is healthy. The unemployment rate for the Great Lakes states dipped below the U.S. average in 1991 and remained there during the 1990's and, for the Great Lakes states collectively, unemployment is at a 30 year low. Canadian and Ontario economic recoveries unfolded later than the U.S. but have now nearly caught up. Ontario unemployment rates are currently at the lowest level since 1990.

Both sides of the border reflect a manufacturing intensity greater than their national economies. The Great Lakes states represent about 27% of national output in manufacturing whereas Ontario is twice as large. The manufacturing sector has many cross-border linkages particularly for the auto industry. About half of the billion dollar-a-day U.S.-Canada trade is tied to the Great Lakes states with Ontario as the most prominent province in this relationship.

**Future Pressures**

Good economic times translate into high levels of consumer spending and home buying. This may cause increased household and business waste generation, increased air pollution, and accelerated land use changes.

**Acknowledgments**

Authors: Steve Thorp, Great Lakes Commission, Ann Arbor, MI, Tom Muir, Environment Canada, Burlington, ON and Mike Zegarac, Environment Canada, Burlington, ON.

## ater Use

### **Assessment:** Unable to assess status until targets are determined

**Purpose**

This indicator measures the amount of water used by residents of the Great Lakes basin. It also indirectly measures the stress to the Great Lakes ecosystem caused by the extraction of this water and the generation of wastewater pollution (there is a direct relationship between the amount of water used and the quantity and quality of wastewater discharged).

**State of the Ecosystem**

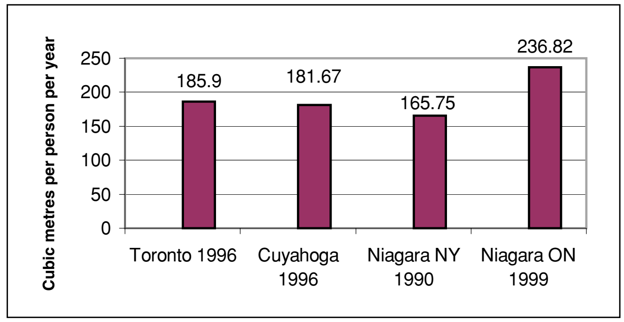
Water use was compared between four sample sites. These included two larger urban cities, Toronto, Ontario and Cuyahoga County, Ohio (which includes Cleveland) and two smaller communities, the Regional Municipality of Niagara, Ontario and Niagara County, New York. Generally, there are not great differences amongst the Great Lakes basin communities in terms of water use per capita, although the Regional Municipality of Niagara, Ontario appears to be using more per capita (by approximately 50 cubic metres each year) than the other municipalities studied. The larger urban communities of Toronto, Ontario and Cuyahoga, Ohio exhibited similar water use patterns per capita. The largely rural community of Niagara County, New York had the lowest per capita water usage rates of the sample, although a bias was possible since there were a small number of residents that were using ground water (and therefore, water use was not recorded).

**Future Pressures**

As Great Lakes populations grow, there will be increasing demand for water for all purposes.

**Acknowledgments**

Authors: Ray Rivers, Rivers Consulting, Campbellville, ON and John Barr, Burlington, ON.



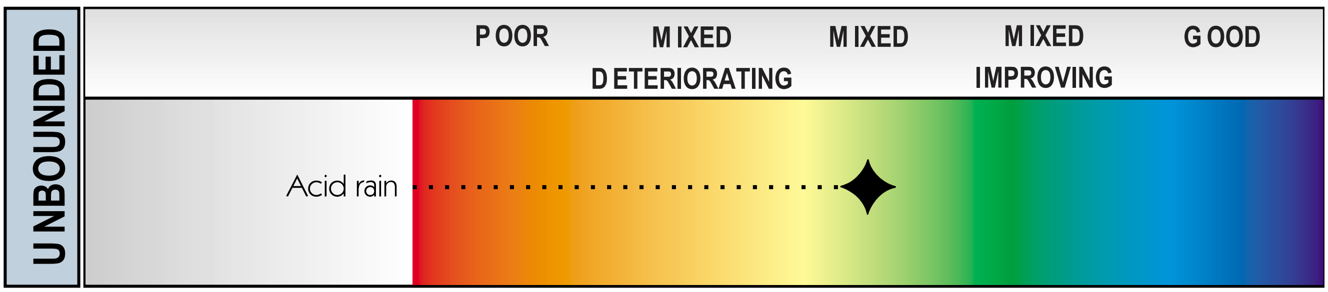

Water use rates of four communities in the Great Lakes basin.

Source: Rivers Consulting and J. Barr Consulting

## 3.7 Unbounded

Some of the Great Lakes indicators do not fit neatly into any of the other ecological categories. These indicators may have application to more than one category or they may reflect issues that affect the Great Lakes but have global origins or implications. One such indicator, acid rain, is included here.

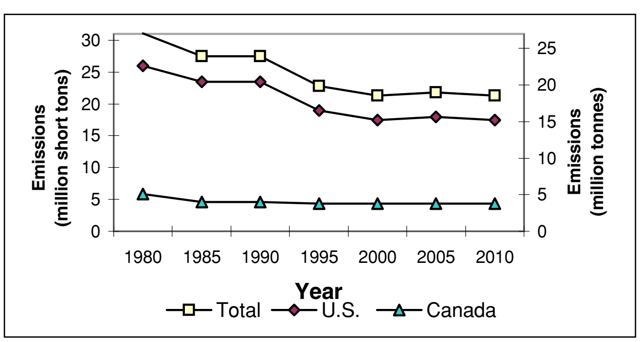
### Unbounded Indicators -Assessment at a Glance




### Acid Rain

**Assessment:** Mixed

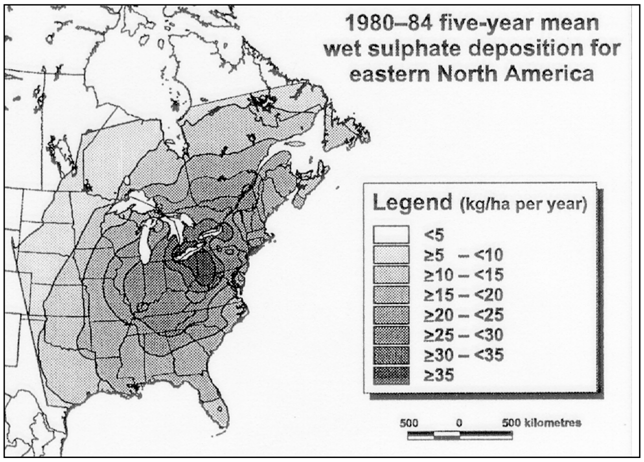
**Purpose**
This indicator assesses the pH levels in precipitation and critical loadings of sulphate to the Great Lakes basin. This indicator can be used to infer the effectiveness of policies to reduce sulphur and nitrogen acidic compounds released to the atmosphere.




Past and predicted sulphur dioxide emissions in Canada, the U.S. and combined. Emissions after 1995 are estimates. Canadian emissions data are preliminary.
Source: Robert Vet, Meteorological Service of Canada

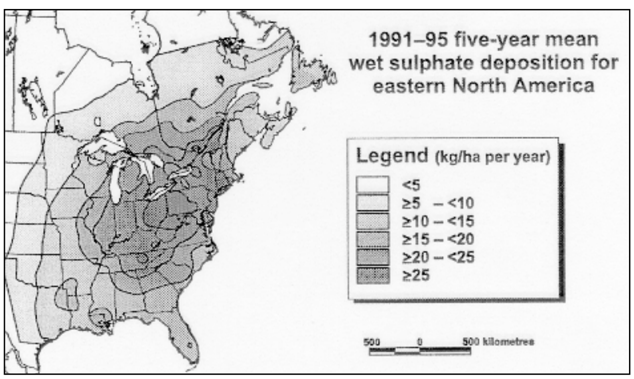
**State of the Ecosystem**
Much of the acidic precipitation in North America falls in areas around and including the Great Lakes basin. The five Great Lakes are so large that acid precipitation has little effect on them directly. Impacts mainly effect vegetation and inland lakes, especially those areas on the Canadian Shield.

$SO_2$ emission levels in Canada and the United States have decreased from 1980 to 1995. U.S. levels are expected to decrease by up to 40% by 2010. Canadian levels dropped 54% from 1980 to 1994 and are expected to remain at these levels. *Despite these efforts, rain is still too acidic throughout most of the Great Lakes region*. Wet sulphate deposition over eastern North America has been compared between two five-year periods, 1980-84 and 1991-95. In response to the decline in $SO_2$ emissions, deposition decreased between the two periods. If $SO_2$ emissions remain relatively constant after the year 2000, as predicted, *it is unlikely that sulphate deposition will change in the coming decade.*




Mean wet sulphate deposition in Eastern North America, 1980-1984.

Source: Robert Vet, Meteorological Service of Canada




Mean wet sulphate deposition in Eastern North America, 1991-1995.

Source: Robert Vet, Meteorological Service of Canada

**Future Pressures**

Population growth from both within and outside the basin may cause increased demands on electrical utility companies, natural resources and an increased number and use of motor vehicles.

**Acknowledgments**

Authors: Dean S. Jeffries, National Water Research Institute, Environment Canada, Burlington, ON and Robert Vet, Meteorological Service of Canada, Environment Canada, Downsview, ON.

From time to time, changes to the suite of Great Lakes indicators will be necessary in order to add, remove or revise indicators. Efforts are currently underway to develop an indicator to assess the status and potential impact of non-native species in the Great Lakes basin. Although details of this indicator have not yet been worked out, an example indicator report for aquatic exotic species is included here.

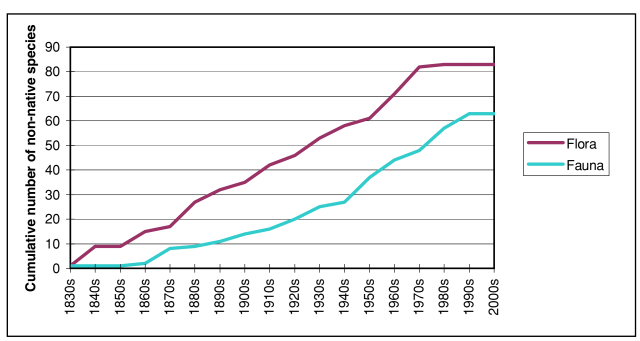
**Assessment:** Poor

**Purpose**

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

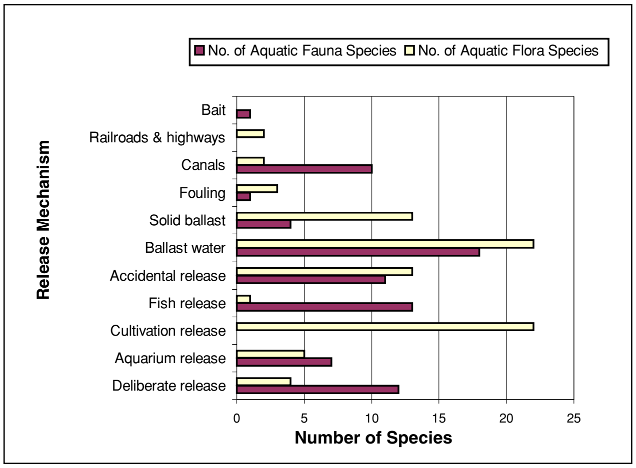
**State of the Ecosystem**

Since the 1830s, there have been 63 non-native aquatic animal (fauna) species introduced into the Great Lakes. Some of the main entry mechanisms include ship ballast water, the deliberate release of fish and other faunal species, and aquarium releases. In terms of aquatic plant species (flora), in almost the same timeframe there have been 83 non-native species introduced into the Great Lakes ecosystem.




Cumulative number of non-native species introduced into the Great Lakes since the 1830s.

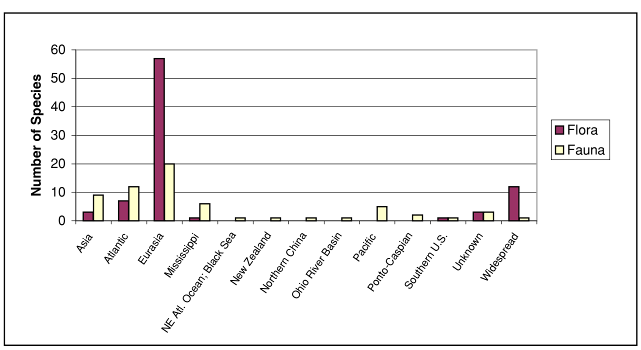
Source: E. Mills, Cornell University, NY




Release mechanisms for non-native species introduced into the Great Lakes.
Source: E. Mills, Cornell University, NY

The main entry mechanisms for aquatic plants include ship ballast water, cultivation release, aquarium releases, and solid ballast from ships.

Even with voluntary and mandatory ballast exchange programs recently implemented in Canada and the United States, new 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.




Regions of origin for non-native species established in the Great Lakes.
Source: E. Mills, Cornell University, NY

**Future Pressures**

Introductions of non-native species will continue because of increasing 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, temperature, and even the previous introduction of key species from outside (making the region potentially more hospitable for the establishment of new invaders).

## Acknowledgments

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

# Section 4
# Future Work on Indicators

## Phase-in Approach

To begin the assessment of the state of the Great Lakes through the use of indicators, 33 summary reports were prepared for SOLEC 2000. These indicators were chosen based on the availability of data and on the cooperation of the report authors. For many of the indicators, the data were incomplete, i.e., lacking time series or geographic coverage, but an initial assessment of the ecosystem component could be made with the information available.

SOLEC organizers were pleased with the number of indicator reports that were generated, but they recognize that additional effort is needed. There is now an expectation that updates can be provided on this first set of indicators at future SOLEC events. Likewise, additional indicators are expected to be phased in at each future SOLEC until the entire suite is fully reported.

## Concept of Tiers

In order to facilitate the implementation of the indicators, they have been grouped into three tiers. Tier 1 indicators are those for which at least some data are believed to exist, and an indicator report can be generated. All 33 indicators in this report are designated Tier 1, along with 10 others. Not all 43 belonging to this group have been reported on because some did not have identified authors. Additional indicator development, refinement and testing of some Tier 1 indicators will continue.

Tier 2 indicators are those for which data are not currently available, but for which an active project is underway. Activities could include establishing a monitoring program, developing the details of the indicator, or conducting research and testing of the indicator. Most of the 10 indicators currently designated Tier 2 are included in the SOLEC Coastal Wetlands category.

An active research effort to fully develop Tier 2 indicators is called the **Great Lakes Coastal Wetlands Monitoring Consortium.** A cooperative agreement between the Great Lakes Commission and U.S. Environmental Protection Agency, Great Lakes National Program Office has been established for the first large scale, binational, collaborative effort to assess the ecological health of Great Lakes coastal wetlands. A consortium brought together by the Great Lakes Commission will:

- design and validate SOLEC indicators to assess the ecological integrity of Great Lakes coastal wetlands;
- design a long-term program to monitor Great Lakes coastal wetlands; and
- create and populate a binational coastal wetlands database accessible to all scientists, decision makers, and the public.

This consortium currently includes Great Lakes wetland scientists and resource managers from both federal governments, states/provinces, non-profit organizations, and academia. Funding for the first two years exceeds $500,000 (U.S.), and the project may be continued for up to six years.

Tier 3 indicators are those for which data do not exist, monitoring programs need to be established, or the indicator itself needs more developmental work and/or testing. There are currently 27 of these “orphans,” with representation of all SOLEC indicator categories. These indicators require deliberate attention before they can be phased into the reporting process at a future SOLEC.

U.S. Environmental Protection Agency/Great Lakes Natioinal Program Office issues an annual request for proposals for projects that help provide progress toward the goals of the Great Lakes Water Quality Agreement. To facilitate development and testing of some of the Tier 3 indicators, projects were requested in 2001 specifically to develop, test and implement "underdeveloped" SOLEC indicators. Up to $300,000 (U.S.) may be awarded to move Tier 3 indicators toward fully implemented, Tier 1 designation.

## Commitments and Ownership

No one organization has the resources or the mandate to examine the state of all the Great Lakes ecosystem components. In collating the available information for the indicator reports, a number of difficulties became apparent while attempting to summarize different sources of information collected using different sampling and analytical methods at different locations at different times. Some differences were impossible to resolve. For the Parties to report on an on-going basis, a monitoring program with consistent protocols would have to be the primary source of the information, and a commitment to maintain such a program would be required.

Many organizations routinely collect and analyze data about some part of the ecosystem. A consensus by environmental management agencies and other interested stakeholders about what information is necessary and sufficient to characterize the state of Great Lakes ecosystem health would facilitate more efficient monitoring and reporting programs. The relative strengths of the agencies could be utilized to improve the timeliness and quality of the data collection and the availability of the information to multiple users.

For state of the Great Lakes reporting to be sustainable, commitments are required for agencies to accept lead roles to collect and interpret data and report on selected indicators prior to each SOLEC. Data for some indicators are distributed throughout several agencies. One agency, or perhaps co-lead agencies, should accept the lead role for the purpose of SOLEC reporting. The lead agency need not necessarily be the same as the one(s) conducting the monitoring, but a close association should exist between the two.

# Section 5
# Biodiversity Investment Areas

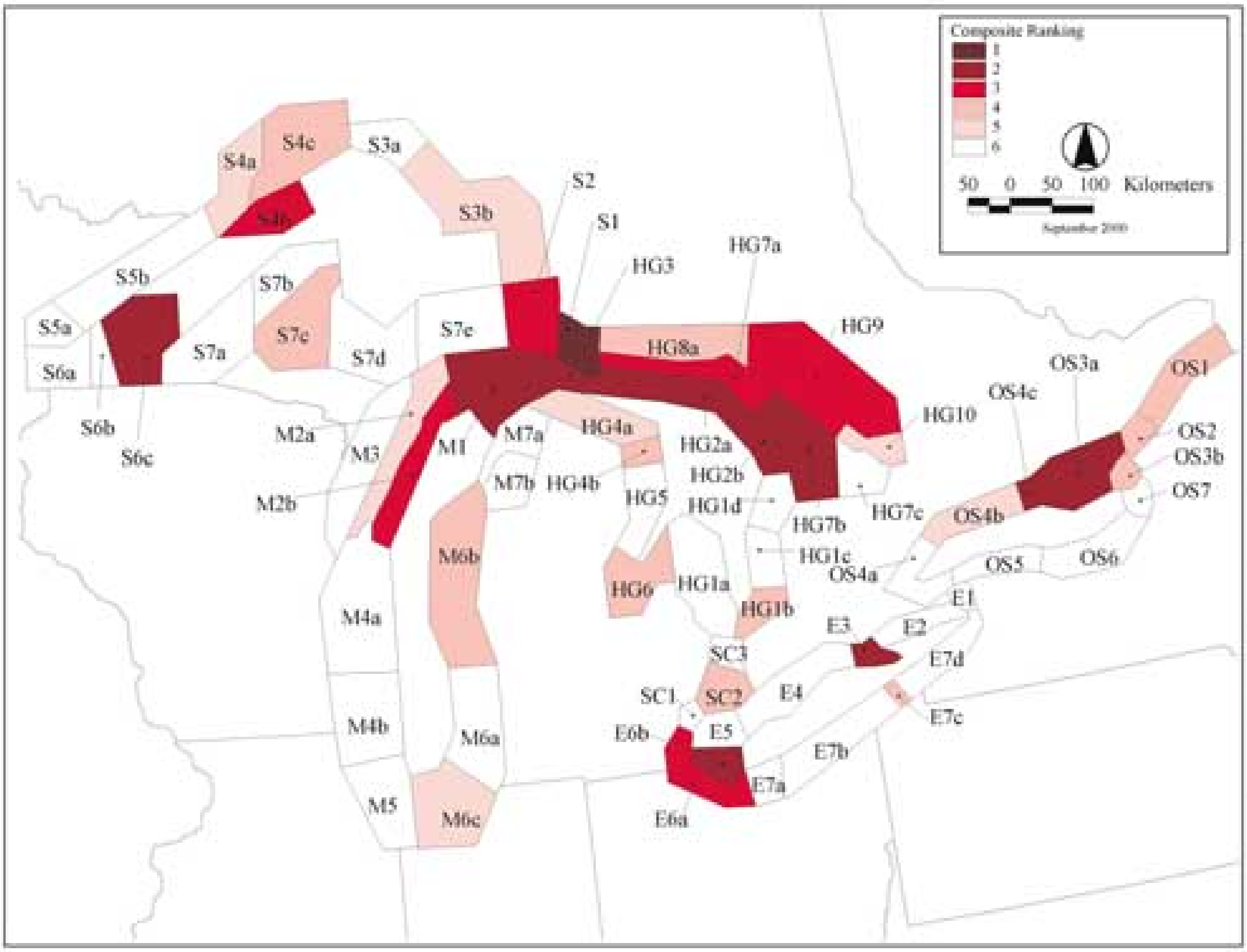
Biodiversity Investment Areas (BIAs) are areas having clusters of biodiversity values, specifically, species or communities of special interest, a diversity of habitats, communities and species, and productivity and integrity. The nearshore terrestrial background paper, *Land by the Lakes, Nearshore Terrestrial Ecosystems*, prepared for SOLEC 1996, coined the phrase to signify areas of unusual biological diversity in need of protection from human impacts. For SOLEC 1998, two additional BIA papers on coastal wetlands and nearshore aquatic habitats further refined the BIA concept. At SOLEC 2000, the BIA work from previous SOLECs on nearshore terrestrial, coastal wetlands, and nearshore aquatic BIAs was integrated.

BIA integration was undertaken to begin to show the relationships amongst nearshore components of the Great Lakes. A series of 70 shoreline units were selected as a basis for the integration analysis. The coastal eco-reaches identified by the 1998 coastal wetlands BIA paper were used as a starting point. In order to fairly address all three nearshore zones (terrestrial, coastal wetlands, aquatic), three broad evaluation criteria were proposed: species or communities of special interest; diversity of habitats, communities and species; and productivity and integrity. A total of ten data sets were identified which could be used to apply the evaluation criteria to the entire Great Lakes shoreline. Data were summarized for each of the 70 shoreline units.

| Tier | Composite ranking combination | Shoreline units within group | Total length of shoreline units in group (km) | % of total shoreline length |
|---|---|---|---|---|
| 1 | AAA | S1 | 687 | 3.6% |
| 2 | AAB | OS3a, OS4c, E3, E6b, HG2a, HG2b, HG3, HG7b, M1, S6c | 3552 | 18.5% |
| 3 | AAC, ABB | E6a, HG7a, HG9, M2b, S2, S4b | 2452 | 12.8% |
| 4 | AAD, ABC, BBB | OS1, OS2, OS3b, E7c, SC2, HG1b, HG4b, HG6, HG8a, M6b, S4c, S7c | 5108 | 26.7% |
| 5 | ABD, ACC, BBC | OS4b, HG4a, HG10, M2a, M6c, S3b, S4a | 1992 | 10.4% |
| 6 | All other combinations | 34 units | 5432 | 28.0% |

Biodiversity Investment Area integration rankings.

Source: Ron Reid, Bobolink Enterprises, Karen Rodriguez, U.S. Environmental Protection Agency-Great Lakes National Program Office, Heather Potter and Michele DePhilip, The Nature Conservancy




Biodiversity Investment Area integration status.

Source: Ron Reid, Bobolink Enterprises, Karen Rodriguez, U.S. Environmental Protection Agency-Great Lakes National Program Office, Heather Potter and Michele DePhilip, The Nature Conservancy

An evaluation ranking was assigned for each of the three criteria for each shoreline unit. Units were then assigned to tiers based on their composite rankings for all three criteria. Shoreline units with the highest overall rankings were highlighted. Clusters of high ranking shoreline units are potential Biodiversity Investment Areas. Thus far, these potential BIAs have been named informally using nearshore terrestrial BIA names from *Land by the Lakes*, or commonly known geographic names.

The results of the rankings for each of the three criteria were compiled to produce composite rankings. The top two tiers encompass just over 22% of the shoreline length in 11 shoreline units. Their distribution dramatically illustrates the importance of the "Mackinac-Manitoulin Arch" - the crescent of significant biodiversity sites that encompasses the northern parts of Lake Michigan, Lake Huron and Georgian Bay. In particular, the outstanding significance of the St. Marys River is noted. Adding the next tier of shoreline units brings the total shoreline encompassed by these priority units to over one-third of the Great Lakes coast, and broadens the distribution across other sections of the lakes.

The results suggest that a few of the previously identified terrestrial BIAs have only medium ranks when coastal wetland and nearshore aquatic data sets are included in the analysis. Eastern Lake

Superior, Chicago Wilderness, and Presque Isle, for example, are terrestrially significant, but did not rank high in the integrated BIA process, a conclusion not well received by those working to restore the areas. It is important to note that while in some areas, such as the southern end of Lake Michigan, a highly developed and hardened shoreline has inhibited land - water interactions, thereby posing a threat to rare terrestrial species, significant but fragmented terrestrial areas remain that need protection and restoration.

Recommendations for further BIA work include:

1. Maps for BIAs need to be updated periodically to accommodate new scientific findings as additional digital data sets are developed.

2. Data contributing to the assessment of Criterion 3, Productivity and Integrity, needs to be refined to include direct measures of current productivity or ecosystem integrity.

3. The United States data set on rare species and communities needs to be refined.

4. A more detailed review of values and potential BIA boundaries is needed, at least for the top four tiers of shoreline units.

5. Long term monitoring of ecosystem health indicators needs to be implemented both within and outside of BIAs.

6. The level of local awareness about the special qualities of BIAs needs to be raised and local support and participation in ecological restoration programs needs to be encouraged. Care must be taken to show that although an area is not as biologically rich as the Mackinac-Manitoulin Arch does not mean it is unimportant and therefore disposable.

# Section 6
# Conclusions

This State of the Great Lakes report represents a new way of reporting. Previously we reported on the state of the ecosystem and on the stressors to the system, but our reports lacked any predictable format or framework. The Parties to the Great Lakes Water Quality Agreement recognized that a means to report on the Great Lakes basin ecosystem in a comprehensive, consistent and understandable way was needed. The Parties have moved from a series of ad hoc indicators, reported in the State of the Great Lakes 1995 and 1997, to a refined and accepted suite of 80 indicators. These indicators will be used by the Parties and other organizations to measure the state of the Great Lakes ecosystem now and in the future.

In determining the state of the Great Lakes for this present report, only 33 of the 80 indicators were assessed. What about the others? In some cases the information is available, but the identification of an author or agency to prepare the report is all that is necessary. In other cases, more work is needed in terms of research and refinement, and monitoring programs may need to be initiated in order to implement these indicators.

The results of those indicator assessments have been summarized within each of the six major groups - human health, open and nearshore waters, coastal wetlands, land and land use, societal, and unbounded, along with a summary of the conditions in each Lake and the interconnecting channels.

Surface waters of the Great Lakes are still amongst the best sources of drinking water in the world, and they continue to serve a large part of the 33 million people who live in the Great Lakes basin. Protection of water at its source, prior to any treatment, is still one of the best means to assure safe drinking water, not to mention maintenance of a healthy aquatic ecosystem. Advisories related to humans eating fish are still in place on all the Great Lakes, even though chemical contamination is decreasing in most species. Contaminant levels will need to continue to decline for many more years before advisories can be lifted, or, in some areas/cases, even modified. New procedures to standardize testing for *E. coli* will help to improve swimming advisories and help beach operators to better protect human health.

## aters

Invasive, non-native aquatic species are the greatest biological threat to Great Lakes aquatic ecosystems. Despite the decline in toxic contamination in many species of Great Lakes fish, as just noted, fish populations continue to be stressed by other causes. These stresses include: weakening of the forage base, food chain disruptions, habitat loss, and competition with, or replacement by, non-native species. Sea lamprey controls since the 1960s, have allowed the rehabilitation of the Great Lakes fishery. However, evidence presented in this report shows that populations of sea lamprey in Northern Lake Huron and the St. Marys River continue to be a problem for fish populations in those areas. The process of habitat improvement through projects such as dam removal and sediment clean-up, as a part of the overall reduction in contaminants, has resulted in increased prey availability for the lamprey as well as increased lamprey spawning habitat. This has created continued dependence on controls well into the future. Suspension of such controls will have an adverse effect on the fisheries.

## etlands

Four of the five indicators for this assessment category show that coastal wetlands continue to decline in both quantity and quality. Over two-thirds of the Great Lakes wetlands have already been lost and many of those remaining are threatened by pressures such as development, drainage, and pollution.

Urban sprawl is the greatest physical threat to high quality natural areas, rare species, farmland, and open space in the Great Lakes basin. The Great Lakes coastline still retains significant, important, and diverse natural areas such as northern Lakes Michigan and Huron, Georgian Bay, and the St. Marys River. These areas are extraordinarily biologically diverse and deserve special protection.

This category of indicators requires considerable work. Stewardship of Great Lakes natural resources is widespread throughout the basin and includes urban ecological restoration, rural conservation of open space, and native preservation of species of cultural significance.

Indicators for both terrestrial and aquatic environments identify invasive, non-native aquatic species as the greatest biological threat to the Great Lakes aquatic ecosystem. Further work is required to document the impact of terrestrial non-native species and their subsequent impacts to the ecosystem.

Assessments for the state of the five Great Lakes and Interconnecting Channels show **generally** that conditions are ***mixed***, with some ecosystem components assessed as good, and others assessed as poor.

# Chemical Acronyms/Terms Used in This Report

| | |
|---|---|
| $\alpha$- and $\gamma$-HCH | Hexachloro-cyclohexane - a manufactured chemical that does not occur naturally in the environment. It exists in eight chemical forms (called isomers). One of these forms, $\gamma$ (gamma)-HCH (also known as lindane) was used as an insecticide on fruit and vegetable crops (including greenhouse vegetables and tobacco) and forest crops (including Christmas trees). It is still used in ointments to treat head and body lice, and scabies. It is also known as BHC (benzene hexachloride). |
| $\mu g/m^3$ | Microgram per cubic metre - unit of measure. |
| atrazine | A common herbicide used on agricultural crops, especially corn. |
| BaP | Benzo-[*a*]-pyrene - one type of PAH (see definition). |
| DDE | Dichlorodiphenyl-dichloroethylene - a degradation product of DDT. |
| DDT | Dichlorodiphenyl-trichloroethane - the first organochlorine pesticide developed (1939). It is persistent in the environment and has been linked to numerous ecosystem effects. It has been banned from use in Canada and the United States. |
| dieldrin | Dieldrin was a popular pesticide for crops such as corn and cotton from 1950-1970. Concerns about damage to the environment and the potential harm to human health led EPA to ban all uses of dieldrin in 1974 except to control termites. In 1987, EPA banned all uses. |
| HCB | Hexachlorobenzene is released primarily as a byproduct of industrial and combustion processes. It was used as an industrial chemical and is currently present as an impurity in pesticides, Hexachlorobenzene is considered to be a persistent, bioaccumulastive toxic substance (PBT). PBTs have serious potential human health and/or environmental effects. |
| heptachlor epoxide | Heptachlor was used extensively in the past for killing insects in homes, buildings, and on food crops, especially corn. Use slowed in the 1970s and stopped in 1988. Heptachlor epoxide is a degradation product of heptachlor and is more commonly found in the environment. |
| mirex | Mirex was used to control fire ants, and as a flame retardant in plastics, rubber, paint, paper, and electrical goods from 1959 to 1972. It has not been manufactured since 1978. |
| nitrate and nitrite | Inorganic chemicals occurring naturally as part of the nitrogen cycle. Nitrate is also used or found in fertilizers as potassium or sodium nitrate. |
| ng/L | Nanogram per litre - unit of measure. |

OCS — Octachlorostyrene - not commercially manufactured, but has been reported to be an inadvertent by-product of certain chemical processes. OCS may also result from various incineration processes. OCS is persistent (i.e., it is resistant to chemical and/or metabolic degradation), has high bioaccumulation potential (i.e., increase in concentration in the upper levels of an aquatic food web) and is toxic.

PAH — Poly-aromatic hydrocarbons - a class of over 100 very stable organic molecules; they are highly carcinogenic but are also very common; they are a standard product of combustion, and are usually found as a mixture of 2 or more.

PCB — Polychlorinated biphenyls - a class of manufactured organic chemicals that contain 209 individual chemicals (known as congeners); there are no known natural sources of PCBs. PCBs contain one or more atoms of chlorine, are resistant to high temperatures, and do not break down in the environment.

PCDD / PCDF — Polychlorinated dibenzo-p-dioxins / polychlorinated dibenzofurans - a group of unwanted by-products of many chemical, industrial and combustion processes. Also found as impurities in some pesticides.

ppm — Parts per million - unit of measure.

toxaphene — An insecticide containing over 670 chemicals; used primarily in the southern United States to control insect pests on cotton and other crops; it was also used to control insect pests on livestock and to kill unwanted fish in lakes. Toxaphene was one of the most heavily used insecticides in the United States until 1982, when it was banned for most uses; all uses were banned in 1990.

# Acknowledgments

The *State of the Great Lakes 2001* preparation team included:

| Environment Canada | United States Environmental Protection Agency |
|---|---|
| Nancy Stadler-Salt, lead | Paul Bertram, lead |
| Harvey Shear | Paul Horvatin |
| Stacey Cherwaty | Karen Rodriguez |

This report contains contributions from over 100 authors, contributors, reviewers and editors. Many of the individuals participated in the preparation of one or more reports assembled in the document Implementing Indicators, Draft for Review, November 2000. Others provided advice, guidance or reviews. Their enthusiasm and collaboration are gratefully acknowledged.

Over 50 governmental and non-governmental sectors were represented by the contributions. We recognize the participation of the following organizations. Those represented by two or more internal organizational units are denoted by *. While we have tried to be thorough, any misrepresentation or oversight is entirely unintentional, and we sincerely regret any omissions.

**Federal**

*Environment Canada
- Canadian Wildlife Service
- Ecosystem Science Directorate
- Environmental Conservation Branch
- Environmental Emergencies Section
- Meteorological Service of Canada
- National Water Research Institute

Fisheries and Oceans Canada
National Oceanic and Atmospheric Administration
U.S. Department of Agriculture - Natural Resources Conservation Service
U.S. Environmental Protection Agency
- Great Lakes National Program Office
- Region 2
- *Region 5

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

*U.S. Geological Survey - Biological Resources Division
- Great Lakes Science Center
  - Lake Ontario Biological Station
  - Lake Superior Biological Station
  - Lake Michigan Ecological Research 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, Foods, and Rural Affairs
Ohio Division of Wildlife
Ohio Division of Natural Resources
Pennsylvania Department of Environmental Protection
Wisconsin Department of Natural Resources

**Municipal**
City of Chicago
City of Toronto

**Aboriginal**
Bad River Tribe
Chippewa Ottawa Treaty Fishery Management Authority
Mohawk Council of Akwesasne

**Academic**
Clemson University, SC
Cornell University, NY
Indiana University, IN
James Madison University, VA
Michigan State University, MI
York University, ON

**Commissions**
Great Lakes Commission
Great Lakes Fishery Commission
International Joint Commission

**Environmental Non-Government Organizations**
Bird Studies Canada
The Nature Conservancy

**Industry**
American Water Works Association
Council of Great Lakes Industries
Private Organizations
Bobolink Enterprises
DynCorp I&ET
Environmental Careers Organization
Rivers Consulting
Private Citizens