State of the Great Lakes 1999

by
the Governments of
Canada
and
the United States of America

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

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Statement of Stewardship

I am proud to take stewardship of the water, land, and air in any way that I can. As I return to my home I pledge to:

1) study the ecology in and of my area
2) teach others about my area's ecology
3) increase my own awareness of the effects that I have on the environment
4) promote the wise use of products and packaging
5) devote time every year to group community service to benefit and beautify the environment
6) participate in the conservation of water, energy and natural resources
7) get involved in local decision-making
8) invite scientists and others to help us
9) do what I know is right

Presented by Grades 5-8 Students at:
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May 14, 1999
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Biodiversity Investment Area Papers

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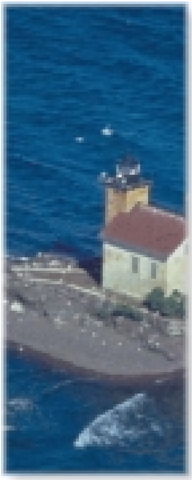
And lastly, thanks must go out to the many reviewers of this report.



Executive Summary

This State of the Great Lakes (1999) report is the third 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 predictable format.

This report is a transition to that indicator-based format, giving information on 19 of the 80 indicators being proposed by the Parties. These 19 indicators were selected as representative of the kinds of information that the Parties will be presenting biennially. They are also indicators for which information was readily available. The indicators are presented in the categories (nearshore terrestrial, coastal wetlands, etc.) under which they were organized for the Parties' Indicator List (Appendix 1).

Not all of the proposed 80 indicators are presently being monitored, and this represents a challenge to the Parties to ensure that information is available in a timely fashion to allow reporting on progress. It should be noted that not all indicators need be reported on every two years. Some lend themselves to less frequent reporting. Nevertheless, information-gathering systems must be put in place to ensure that collection of information is in hand. A full description of the indicators can be found in the Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 4, available on line at: www.cciw.ca/solec/ or www.epa.gov/glnpo/solec/98/.

The 80 indicators, however, do not easily lend themselves to the questions most frequently asked by the public: How's the water? Is it safe to drink? How's the air? Is it safe to breathe? And so forth. Therefore, for SOLEC 2000, the 80 indicators will be grouped and reported on within seven environmental compartments: air, water, land, sediments, biota, fish, and humans; and additionally, issue by issue including: persistent toxic chemicals, nutrients, exotic species, habitat, climate change, and stewardship.

Given the incomplete nature of the information available for the 80 indicators, the Parties can not provide a detailed quantitative assessment of the State of the Lakes. The Parties however, do provide the following overall qualitative assessment: The state of the Great Lakes in 1999 has not changed significantly from the state reported on in 1997. With respect to herring gull eggs, analyses show that most contaminants at most sites are continuing to decline at a rate similar to that over the last decade or two. The Parties also note that the emergence of the round goby as yet another non-native species to become established in the Lakes, could pose a threat to the integrity of the biological community in the Great Lakes.

Another feature of this report is the description of Biodiversity Investment Areas (BIAs). BIAs were first reported in the State of the Great Lakes (1997) report for the terrestrial nearshore areas. The BIA concept has been expanded to include coastal wetlands and open water areas of the Lakes. Biodiversity Investment Areas are a concept intended to recognize the importance of protecting the rich biological diversity of the Great Lakes ecosystem and the many kinds of habitat needed to support that diversity. The concept is also intended to provide a locally based recognition and support for areas of key biological importance, whether relatively undisturbed, or degraded. Such areas play a key role in maintaining the integrity of the ecosystem and its long term viability. The idea is not that some areas can be written off as not being important, but that some areas are of such importance that special efforts are needed to ensure preservation. The BIA papers are also available on line at: www.cciw.ca/solec/ or www.epa.gov/glnpo/solec/98/.

1. Introduction

The State of the Great Lakes (1999) report takes a significant departure from the format of the previous State of the Great Lakes reports. In the past a general overview of the Great Lakes ecosystem was presented, however, there was no pattern or consistency in the reporting method. The reports summarized information to describe the state of the ecosystem, and the stressors on the system, but lacked any predictable format or framework. It was recognized that a means to report on the system in a comprehensive, consistent and understandable way was needed. This State of the Great Lakes report describes the *process* necessary to get to that stage. This process is not instantaneous and will take several years before all the major components of the Great Lakes ecosystem will be reported on. Future State of the Great Lakes reports will communicate more completely on the health of the ecosystem but the State of the Great Lakes (1999) report is a *transition* to a more unified reporting method.

The State of the Lakes Ecosystem Conferences (SOLEC) were established by the governments of Canada and the United States (the Parties to the Great Lakes Water Quality Agreement) in 1992 to provide independent reporting on the state of health of the Great Lakes basin ecosystem. The Parties directed that SOLEC be a science-based reporting forum. SOLEC has not presented information on programs, because the Parties firmly believe that a forum devoted to program achievements could lead to the presentation of information that would not be particularly useful in assessing progress. Comparison of jurisdictional approaches, dollars spent, reports issued, fines levied etc. would not, in and of itself, be very useful. Rather, by keeping the discussions to science-based assessments of the state of the Lakes, and the stresses on the Lakes, participants at SOLEC have participated in an open process where the "playing field" was level, and any view was acceptable, provided it was based in science, and backed by verifiable data.

SOLEC also 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 the 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 exchange of information.

Starting at SOLEC 94, the governments reported on basin-wide conditions relating to: a) aquatic ecosystem health; b) human health; c) aquatic habitat and wetlands; d) nutrients; e) contaminants; and f) the economy. These categories ensured that major components of the ecosystem were covered, as well as a major component of human activity (the economy). The organizers developed a series of ad hoc indicators against which to report progress or provide an assessment of the state of these components. These indicators were based on the best professional judgment of a number of scientists and mangers who had prepared background papers on the subject components. The reader is referred to the State of the Great Lakes 1995 for more detail (www.cciw.ca/solec/ and www.epa.gov/glnpo/solec/). A similar process was followed for SOLEC 96, where the focus was on the nearshore environment, including the terrestrial nearshore.

In planning for SOLEC 98, the organizers wanted to support the further 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 provide a predictable set of signs of the health of the system, and the progress being made to remedy existing problems.

The demand for high-quality, relevant data concerning the health of various components of the Great Lakes ecosystem has been escalating rapidly for the past decade or so. The U.S. and Canada have spent billions of dollars and uncounted hours attempting to reverse the effects of cultural eutrophication, toxic chemical pollution, over-fishing, habitat destruction, introduced species, etc. Environmental management agencies are being asked to demonstrate that past programs have been successful and that the success of future or continuing programs will be commensurate with the resources expended (financial and personnel time). At the same time, in both countries, the amount of taxpayers dollars being devoted to Great Lakes environment issues is decreasing. The demand for high quality data, while operating with limited resources, is forcing environmental and natural resource agencies to be more selective and more efficient in the collection and analysis of data.

The most efficient data collection efforts will be those that are cost-effective and relevant to multiple users. A consensus about what information is necessary and sufficient to characterize the state of Great Lakes ecosystem health and to measure progress toward ecosystem goals would facilitate efficient monitoring and reporting programs.

The State of the Great Lakes (1999) represents a transition between reporting on the ad hoc indicators from 1994 and 1996, and reporting on an accepted suite of indicators. The proposed suite consists of 80 indicators and can be found in full with a brief description in Appendix 1. We have tried to link to information presented in 1994-1996 in a form consistent with the proposed suite of indicators. The update is not comprehensive in terms of what has been presented in the past, nor is it comprehensive in terms of reporting on all 80 indicators. Some of these indicators will require agencies to collect additional data. Others will require the analysis and synthesis of data from non-traditional sources, such as municipalities, private sector or volunteer organizations. Still others will require further development through research before they can be used as routine reporting tools. It is the intention of the Parties to use indicators as a basis for monitoring, and as a focus for some research. Clearly there is a period of phasing in the indicators, and the Parties expect to be reporting on all the indicators within the next 10 years.

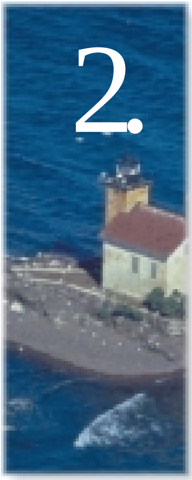
This has not been the only indicator initiative in the Great Lakes basin. Many other groups have developed indicators for their own use. The process to develop a suite of basin-wide indicators has tried to use and build upon the work of others as much as possible. A set of indicators that is relevant to both the Parties and other organizations will prevent a dilution of monitoring effort for competing purposes, and will foster cooperation amongst all agencies for the common good of the Great Lakes ecosystem.

Another major thrust for the Parties has been the development of the Biodiversity Investment Area (BIA) concept. This 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. The idea of highlighting areas of significant natural biodiversity and habitat value for conservation was well received in 1996, but SOLEC participants demanded more. They wanted an analysis of the proposed areas in terms of species and habitats, and the importance of the area to the overall health of the Great Lakes. Therefore, at SOLEC 98, three papers were presented, examining the terrestrial nearshore in some detail, as well as coastal wetlands and aquatic ecosystems. The development of the BIA concept is at different stages, with the terrestrial being the most highly developed, and the aquatic ecosystem BIA the least developed. It is the intention of the Parties to continue with the development and refinement of the BIA concept and to report on progress at SOLEC 2000. The BIAs are discussed in more detail in Chapter 4.

There are four papers related to this report that give further details on the indicator process and the BIA concept:

- Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 4
- Biodiversity Investment Areas:
  - Nearshore Terrestrial Ecosystems
  - Coastal Wetland Ecosystems, Identification of "Eco-Reaches" of Great Lakes Coastal Wetlands
  - Aquatic Ecosystems - Aquatic Biodiversity Investment Areas in the Great Lakes Basin: Identification and Validation

These reports are available for viewing or downloading from the SOLEC web sites: www.cciw.ca/solec/ or www.epa.gov/glnpo/solec/98/.



2. Indicators

Canada and the United States have invested billions of dollars to improve the health of the Great Lakes and to meet the goals of the Great Lakes Water Quality Agreement (GLWQA); but how do the Parties know if they are actually making progress? Do they know what to measure, and do they have an easily understood way of reporting findings? A comprehensive set of Great Lakes basin indicators will help to assess the present condition of the Great Lakes and to determine how much more is needed to meet the goals of the GLWQA. Through SOLEC, a comprehensive suite of basin-wide indicators (the Indicators List) is being established in order to determine the health of the Great Lakes basin ecosystem and report on that health in a consistent manner.

2.1 What is an Indicator?

An indicator is a piece of evidence or signal that tells us something about the conditions around us. It is a tool that gives a clue about the "bigger picture" by looking at a small piece of the puzzle, or at several pieces together. For example, atmospheric pressure is an indicator of the weather to a sailor or a pilot. To a doctor, blood pressure provides a clue about the overall health of a patient, and to an economist, gross domestic product (GDP) gives a snapshot of the state of a country's economy. Similarly, environmental indicators provide bits of information that are useful to us to assess our surroundings.

Glossary of Terms (Figure 1 outlines the relationship between these terms)

Vision A general description of the desired state of a lake, geographic area, or region that is expressed by a group of stakeholders. A vision statement provides a description of a desired state - providing direction and establishing a horizon to be sought.

Goal A condition or state desired to be brought about through a course of action or program. Goals are usually qualitative statements that provide direction for plans and projects.

Objective Specific descriptions of the state or condition that must be met in order to achieve goals and the vision.

Indicator A parameter or value that reflects the condition of an environmental (or human health) component, usually with a significance that extends beyond the measurement or value itself. Indicators provide the means to assess progress toward an objective.

Data Point A single measurement of an environmental feature. Data points may be combined to serve as an indicator.

Target Specific, attainable, quantitative endpoint or reference values for an indicator that provides the context for assessing whether or not an objective is being met.

Each of the indicators above provides information about conditions at a particular point in time. However, we also would like information about trends over time. Is the atmospheric pressure rising, falling or staying the same? Indicators measured repeatedly over time provide the basis for tracking trends in environmental conditions. Also, by looking at a number of indicators together, we can assess whether the whole system is getting better or worse or staying the same.

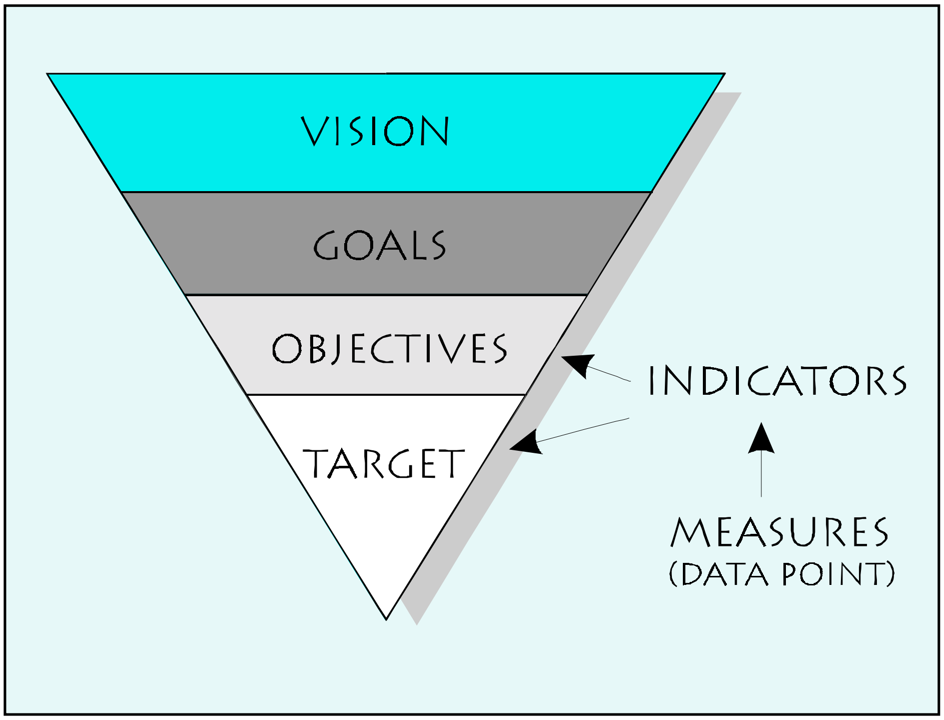


Figure 1. Conceptual Model of the Relationships between Indicators, Measures, Targets, Objectives, Goals and Visions.

An indicator is more than a data point. It consists of both a value (which may be a direct environmental measurement or may be derived from measurements) and a target or reference point. An indicator is intended to be used, alone or in combination with other indicators, to assess progress toward one or more objectives. In addition, to be widely used by decision-makers and others, indicators should be readily understood by the general public.

2.2 Types of Indicators

There are several classification schemes or models for indicators, one of which is the State—Pressure—Human Activity (Response) model. Because of it's simplicity and broad applicability, this is a widely accepted classification scheme and the one used for the Indicator List.

State: These indicators address the state of the environment, the quality and quantity of natural resources, and the state of human and ecological health.

Pressure: These indicators describe natural processes and human activities that impact, stress or pose a threat to environmental quality.

Human Activity (Response): These indicators include individual and collective actions to halt, mitigate, adapt to, or prevent damage to the environment. They also include actions for the preservation and the conservation of the environment and natural resources.

These three indicator types are closely linked. For example, the *pressure* (or stressor) of a particular pollutant entering a system may cause a change of *state* of some species (i.e. population declines) which may, in turn, cause a *response* of (additional) restrictions on the discharge of the pollutant. The additional restrictions reduce the *pressure* which improves the *state*.

2.3 Why the Parties Need Indicators for the Great Lakes Basin Ecosystem

Assessing the health of something as large and complex as the Great Lakes basin ecosystem is a significant challenge - the Lakes contain one fifth of the world's fresh water, there are over 10,000 miles (17,000 kilometres) of shoreline, the basin consists of over 200,000 square miles (520,000 square kilometres) of land, and about 33.5 million people reside within the basin! Add to this a political complexity of two nations, eight states, two provinces, and hundreds of municipal and local governments. A set of Great Lakes basin ecosystem indicators will enable the Great Lakes community — government and non-government organizations, academia, industry, and individual citizens — to work together within a consistent framework to assess and monitor changes in the state of the ecosystem.

For more geographical, physical and historical information on the Great Lakes basin, have a look at these *great* Great Lakes websites:

www.great-lakes.net

www.cciw.ca/glimr

2.4 Why Should There be Agreement on a Suite of Indicators?

High quality, relevant data that concerns the health of various components of the Great Lakes ecosystem is in demand and this demand has been escalating rapidly for the past decade or so. However, in both Canada and the U.S., the amount of taxpayers dollars being devoted to Great Lakes environment issues has been decreasing. This has forced environmental and natural resource agencies to be more selective and more efficient in the collection and analysis of data.

Efficient data collection efforts are cost-effective and also relevant to multiple users. No one organization has the resources or the mandate to examine the state of the entire system. However, dozens of organizations and thousands of individuals routinely collect data, analyze them, and report on parts of the ecosystem. An understanding of what information is necessary and sufficient to characterize the state of

Great Lakes ecosystem health *would* facilitate efficient monitoring and reporting programs. Shared databases *would* provide easier access to relevant supporting data, and the relative strengths of the agencies *could* be utilized to improve the timeliness and quality of the data collection.

Achieving consensus on a set of core indicators means that individual programs and jurisdictions may continue to maintain their own unique indicators. Individual user groups may need to retain certain indicators or other data requirements that are not shared by other groups or needed by the core set of indicators. However, the Indicators List is expected to influence future monitoring and data gathering efforts for a common broad scale set of indicators.

2.5 The Process of Selecting Indicators

Much work has gone into the development of the suite of Great Lakes indicators. Over 150 people from various agencies, industry, academia, and other individuals have been involved, bringing a wealth of expertise to the process.

There will never be a list that every stakeholder in the basin agrees is optimum. However, reviews by stakeholders have been a very important part of the process. Three separate reviews have taken place, and comments incorporated so that the list presented represents many viewpoints. For many of the SOLEC Indicators that are presented in Appendix 1, more research or information is needed before the indicator can be used and data collected for it. In addition, this core set of indicators is flexible enough to expand to take into account new emerging issues in the future. This is a living list, one that can be modified as issues change or new ones arise.

2.6 The Indicator List

The Indicator List currently contains 80 indicators that together can be used to assess the health of the major components of the Great Lakes basin ecosystem. The list is organized by the seven groups and then further categorized by indicator type within each group (State, Pressure, or Human Activity). A listing of the 80 indicators with a brief description can be found in Appendix 1.

For further information on the indicators and how they were selected, please see the report Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 4. This report is available for viewing or downloading from the SOLEC web sites: www.cciw.ca/solec/ or www.epa.gov/glnpo/solec/98/.

2.7 How Relevant are the Indicators?

In an era of rapid ecosystem change, the Indicator List must be flexible enough so that targets or endpoints within an indicator, or even the addition or removal of complete indicators as future emerging issues arise, in order for the list to remain relevant.

In addition to this, the indicator selection process has tried to be relevant to the work of many groups. The Indicator List was developed according to the categories of open and nearshore waters, coastal wetlands, nearshore terrestrial, human health, land use, societal and unbounded (these are indicators that did not neatly fit into *one* of the other categories or that may have more global origins or implications). These groupings are convenient for reporting, but they represent only one of many ways to organize information about the Great Lakes. Depending on the user's perspective, other groupings will be more convenient or will provide insight to aspects of the Great Lakes that differ from the groupings in the Indicator List.

Each of the proposed indicators has been evaluated for relevance to several other organizational categories, and the results are displayed in Appendix 2 on pages 77-85. Included are categories of Indicator Type (state, pressure, human activity), Environmental Compartments (air, water, land etc.), Issues (toxics, nutrients, exotics etc.), GLWQA Annexes, GLWQA Beneficial Use Impairments, IJC Desired Outcomes, and Great Lakes Fish Community Objectives. Further explanation of these categories can also be found in Appendix 2.

2.8 Unfinished Business

The proposed indicators in the Indicator List are not complete, for some indicators further research is necessary to fill in the details, for most indicators some fine-tuning is necessary, and for the suite of indicators as a whole, general acceptance by agencies and stakeholders, and commitment to do long term monitoring and data collection is critical.

What is the State of the Great Lakes in 1999?

This section provides an update and overview of the health of some components of the Great Lakes ecosystem. Since the last State of the Great Lakes Report in 1997, where simple, general indicators were presented, some improvements in reporting have been made, as just described in Chapter 2. A new suite of indicators has been assembled that provides a more organized and detailed look at the overall health of the basin (Appendix 1). Over the next several years the Parties intend that these indicators become the basis of their reporting on progress under the GLWQA. In this present report we have selected some sample indicators. The indicators presented are not chosen on the basis of their importance within the suite of 80 indicators, but rather on their data availability and that they represent different components of ecosystem health. This is only meant to give a flavour of future, more comprehensive reporting. Many other equally important indicators will require a change in monitoring programs before they can be reported on in a quantitative and comprehensive manner. Others will require further research and development. While efforts were made for the descriptions and illustrations presented in this section to directly relate to the indicators as described in Appendix 1, in some cases preliminary data were used in order to present a proposed approach for future reporting.

As stated previously, this State of the Great Lakes report is a transition to a more unified reporting method. The seven categories of indicators evolved from SOLEC 94 and SOLEC 96. The categories were used to more readily involve a large number of people in the development of the Indicator List, so that we may more fully know the status of the health of the Great Lakes ecosystem. As such, and using the state-pressure-human activity model, 80 indicators were deemed necessary to form a rich base for determining overall basin health.

The 80 indicators, however, do not easily lend themselves to the questions most frequently asked by the public: How's the water? Is it safe to drink? How's the air? Is it safe to breathe? And so forth. Therefore, for SOLEC 2000, the 80 indicators will be grouped and reported on within seven environmental compartments: air, water, land, sediments, biota, fish, and humans; and additionally, issue by issue including: persistent toxic chemicals, nutrients, exotic species, habitat, climate change, and stewardship.

For example, of the 80 indicators, 14 are directly concerned with the waters of the Great Lakes (see Appendix 2 for a breakdown of the indicators by environmental compartment, issue, and other groupings). By analyzing the monitoring data of the 14 and aggregating the results, a picture of the health of the waters of the Great Lakes should emerge. Currently, however, data may not be available for all 14 indicators so the picture will be incomplete.

As capacity to monitor and report on the 14 water indicators builds over the next ten years, a more complete answer to the questions about water posed by the public will emerge. Gaps will no doubt be identified that require both an adjustment in the number of indicators needed and a fine tuning of indicators in order to report more fully. For example, the present 14 water indicators do not include a direct indicator of tributary health. Yet the hundreds of tributaries feeding the Great Lakes greatly affect lake health. Additional indicators may therefore be needed. Over time and with such adjustments, the indicators concerned with water will present us with a relatively complete report on the status of the waters. This will be true of the other environmental compartments and issues.

Over the next ten years, beginning with SOLEC 2000, State of the Great Lakes reports will uncover other indicator issues and gaps. Steps will be taken to modify, adjust, and improve the indicators and associated monitoring of these indicators. In time, reporting on the health of the Great Lakes ecosystem will provide all Great Lakes residents with a good understanding of the basin's overall health.

The indicators presented here represent each of the geographical, biological and anthropological components of the Great Lakes basin ecosystem. For each indicator, a short overview is followed by a description of the indicator, with examples of the data available for that indicator. For sources of information on each of the indicators presented here, please see pages 98-101. The following is a list of indicators described in this section:

Nearshore and Open Waters
- Sea Lamprey
- Native Unionid Mussels
- Benthos Diversity and Abundance
- Phosphorus Concentrations and Loadings
- Contaminants in Colonial Nesting Waterbirds
- Atmospheric Deposition of Toxic Chemicals

Coastal Wetlands
- Wetland Bird Diversity and Abundance
- Gain in Restored Coastal Wetland Area
- Sediment Flowing into Coastal Wetlands

Nearshore Terrestrial
- Area, Quality and Protection of Special Lakeshore Communities

Land Use
- Sustainable Agricultural Practices
- Breeding Bird Diversity and Abundance

Human Health
- Fecal Pollution Levels of Nearshore Recreational Waters
- Chemical Contaminants in Fish Tissue
- Chemical Contaminant Intake from Air, Water, Soil and Food
- Air Quality
- Chemical Contaminants in Human Tissue

Societal
- Citizen/Community Place-Based Stewardship Activities

Unbounded
- Acid Rain

3.1 Indicators

3.1.1 Nearshore and Open Waters

The **nearshore waters** of the Great Lakes largely occupy a band of varying width around the perimeter of each lake between the land and the deeper offshore waters of the lake. Also included as nearshore waters are the Great Lakes connecting channels, and the lower reaches of tributaries that are influenced by changes in water levels in the Great Lakes. The **open waters** of the Great Lakes are all of the waters beyond the lakeward edge of the nearshore waters.

Virtually all species of Great Lakes fish use the nearshore waters for one or more critical life stages or functions. The nearshore waters are areas of permanent residence for some fishes, migratory pathways for anadromous fishes, and temporary feeding or nursery grounds for other species from the offshore waters. Only the deepwater ciscoes (members of the whitefish family) and the deepwater sculpin avoid and are rarely found in the nearshore waters. Fish species diversity and production in the nearshore waters are higher than in offshore waters; they also vary from lake to lake and are generally highest in the shallower, more enriched embayments with large tributary systems.

Human activities have substantially altered the Great Lakes basin landscape and the nearshore waters element of the basin ecosystem. Some of the most significant stresses include:

- High density patterns of settlement, development, and population growth;
- Agricultural settlement in the southern portion of the basin created an abundance of food and fibre causing increased nutrient and pesticide loading;
- High usage of surface water for drinking, manufacturing, power production, and waste disposal into tributaries;
- Navigational structures such as dams and canals; and
- Development of sheltered areas into marinas and deepwater ports.

The offshore waters of the Great Lakes are also subject to many of the same stresses as the nearshore environment plus some unique offshore issues. Atmospheric deposition of contaminants, nutrient loadings, accumulation of toxics in open water fish species, invasion of exotic species, and the alteration of fish communities and loss of biodiversity associated with over-fishing and fish stocking practices are some of the on-going issues that face Great Lakes managers today.

Note: The numbers following the indicator name (here and in all of the following sections) are a means of identifying the indicator in the electronic database.

Sea Lamprey

Pressure Indicator (18)

The sea lamprey (*Petromyzon marinus*) is a parasitic aquatic vertebrate native to the Atlantic Ocean that is able to spawn and live entirely in fresh water. It was first found in Lake Ontario in 1835 and had made its way to Lake Erie by 1921. From there, this rapidly colonizing species spread quickly into the upper Great Lakes and was found in Lake Huron in 1932, Lake Michigan in 1936, and Lake Superior in 1946. The sea lamprey is still found in great abundance in the Upper Great Lakes.

The long narrow body of the sea lamprey greatly resembles an eel and has a characteristic round, tooth-filled mouth that it uses to attach to fish. Adults spawn in streams including portions of the St Marys River. Juvenile stages live in stream sediments and feed on organic matter. In the adult stage, this aggressive species feeds on body fluids of Great Lakes fish which often results in the scarring and/or subsequent death of the host individual. The sea lamprey is not selective in its feeding as it preys on all species of large fish including salmon, lake trout, whitefish, walleye and chubs. During its adult stage, it is possible that an individual sea lamprey can cause the death of more than 40 pounds of fish.

Control measures managed by the Great Lakes Fishery Commission and supported by federal, provincial, state and tribal governments has brought the lamprey population under control in most areas. Methods of control include introduction of sterile-males in order to decrease spawning success, lampricide treatments and barriers in streams to prevent the species from reaching spawning areas. The control programs have allowed the re-emergence of some of the fish species which seemed to have previously disappeared from the Great Lakes. In Lake Michigan, sea lamprey numbers are currently 10 percent of their maximum populations in the 1950s.

This indicator measures the number of spawning run adult sea lampreys and the wounding rates on large salmonids in order to assess the impact of the species on other fish populations in the Great Lakes.

The information presented in Figure 2 shows estimates of parasitic phase sea lamprey populations throughout the Great Lakes. Note that Lake Huron populations remain at very high levels since the early 1980s because of large spawning populations in the St. Marys River. Fishery agencies and the Great Lakes Fishery Commission are concerned about the pattern of increase in Lake Michigan, but generally believe that this may be a result of "spill over" from Lake Huron and the St. Marys River. These agencies are also concerned about the pattern of increase in Lake Erie, but feel that with enhanced assessment during 1998, they have identified and will have treated all sea lamprey spawning streams in 1999. One could expect a decline in parasitic sea lamprey in Lake Erie during 2000 and spawners in 2001. Lake Superior populations (only U.S. waters - no historic Canadian data) remain at low levels because of successful control. Lake Ontario populations have also remained constant in recent years because of adequate control.

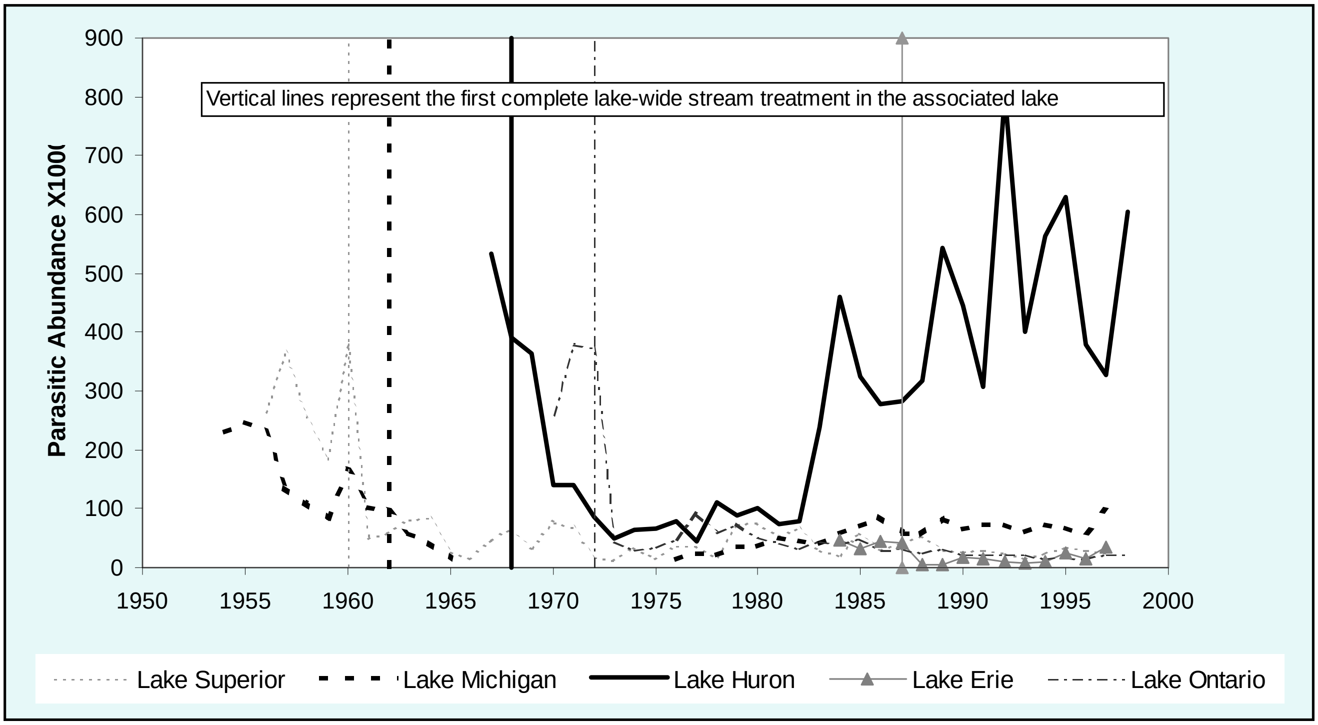


Figure 2. Estimated Parasitic-phase Sea Lamprey in the Five Great Lakes (1950-present).
Source: Great Lakes Fishery Commission, 1999.

Native Unionid Mussels

State Indicator (68)

Native Unionids (clams) are the largest and longest-lived invertebrates in the Great Lakes basin and are key players in the movement of organic and inorganic particulate matter between the sediment layer and overlying water column. Native Unionid populations are generally highly vulnerable to impact and even extirpation by invading zebra mussels (*Dreissena sp.).* Unionid mortality results both from attachment of zebra mussels to their shells (biofouling) and from food competition with zebra mussels. Mortality can occur within two years of the initial zebra mussel invasion, and the rate generally varies directly with zebra mussel population density. The type of habitat occupied by the Unionids also strongly influences the impact from zebra mussels. For example, Unionids may be able to survive in soft-bottomed habitats where they can burrow deeply and suffocate zebra mussels that attach to their shells. Unionids may also survive better in free-flowing streams than in streams with dams where zebra mussel populations rarely reach densities high enough to adversely affect Unionid populations.

This indicator assesses the distribution and reproductive output of the Native Unionid mussel. From data collected, information can be derived concerning the impact of the invading zebra mussel on Unionid mussels.

The species diversity and density of Unionids has severely declined in Lake Erie, the Detroit River, and Lake St. Clair since the arrival of zebra mussels there in the mid-1980s. Species diversity of Unionids in these areas has dropped from an average of 16 in the early years to less than one in recent years with many of these sites no longer supporting Unionids. Figures 3a and b illustrate the increase in zebra mussel infestation since introduction in 1986 at Puce, Ontario located on Lake St. Clair and the associated decrease in native species in the years following. Within seven years of the introduction of zebra mussels into Lake St. Clair, the Unionid population at Puce appears to have been eliminated. Changes in the density of living Unionids and zebra mussel infestation in the St. Lawrence River from 1992 to 1994 are shown in Figure 4. Data suggest that Unionids will be eliminated within four or five years of zebra mussel invasion should the zebra mussel population grow to sufficient levels (>6000/m^2).

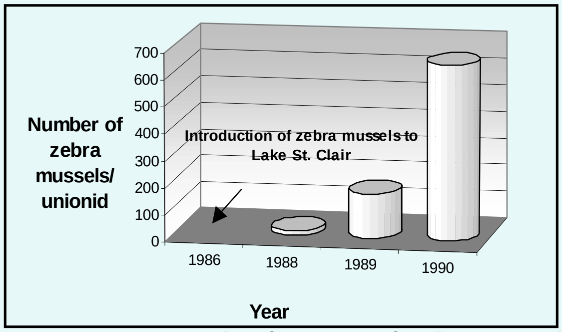


Figure 3a. Annual Infestation of Zebra Mussels on Unionids at Puce, Ontario in Lake St. Clair.
Source: Gillis and Mackie, 1994.

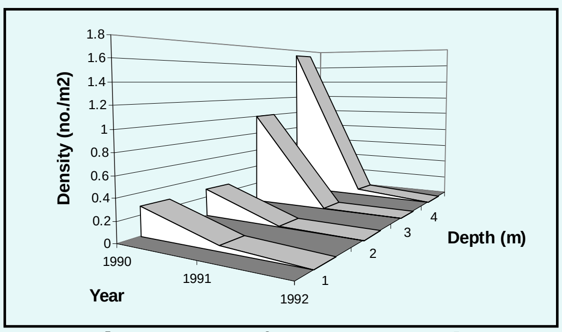


Figure 3b. Density of Living Unionidae at Puce, Ontario in Lake St. Clair.
Source: Gillis and Mackie, 1994.

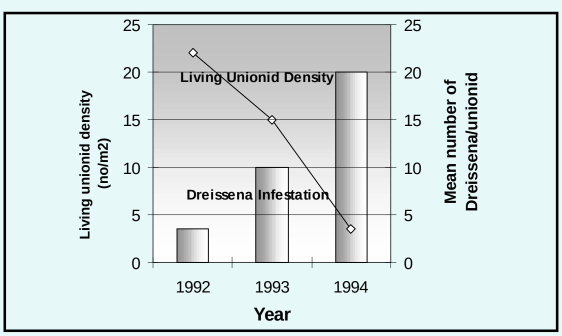


Figure 4. Changes in Living Unionid Density in response to Zebra Mussel Infestation in the Soulanges Canal, St. Lawrence River.
Source: Ricciardi, Whoriskey and Rasmussen, 1995.

An encouraging example of a surviving Unionid population in Metzger Marsh, Lake Erie illustrates how crucial localized habitat conditions are to the survival of native species. In 1994 zebra mussels had been found colonizing all emergent vegetation and rocks at this site. In 1996 during the dewatering of the marsh as part of a restoration project, 22 species of native clams were discovered including several threatened species. Zebra mussel colonization was evident on less than 1% of the 7000 clams collected. In this case it is likely that the specific sediment type and water temperatures of this wetland allowed for the co-existence of the various species of mussels. Since the initial discovery, live native clams have been found at two other coastal wetland sites.

Benthos Diversity and Abundance

State Indicator (104)

The benthic community includes the variety of diverse organisms that call the lake bottom their homes. The species diversity and abundance of benthic invertebrates is an ideal indicator of the impacts of human induced stress in aquatic ecosystems. They live longer than many free floating organisms, they are relatively sedentary (which makes sampling easy), and they reflect the effects of local environmental conditions. Many species of benthos feed on organic material produced in the open water zone and fish then feed on the benthos. This provides a link between open water production and higher trophic levels within the aquatic food chain.

If the historical changes in benthic community structure relative to human induced stresses, and the tolerances of individual species to those stresses, are known, we can make an assessment of the present status of the benthic community. This assessment can provide a consistent, precise indicator of environmental quality in the nearshore region.

In a study carried out from 1991 to 1993 by Environment Canada's National Water Research Institute in Ontario, nearshore locations were visited throughout the Great Lakes to establish a reference database describing natural invertebrate community assemblages. Two hundred and fifty-two locations relatively unaffected by pollution were chosen as acceptable reference sites. One hundred and sixty-two species of invertebrates were identified with the 10 most abundant accounting for more than 70% of all the organisms found (Figure 5). Oligochaetes were the second most diverse group of benthic organisms with 40 species recorded (the most diverse group were the Chironomidae or midge larvae).

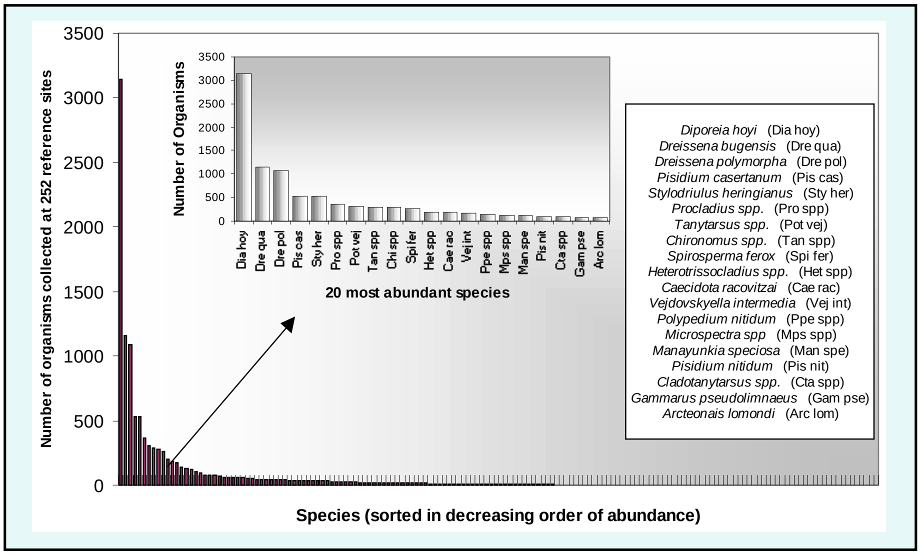


Figure 5. Abundance of Invertebrate Benthic Species Collected at 252 Sites around the Great Lakes.
Source: Reynoldson and Day, 1998.

One index often used to assess the relative health of the benthic community is the abundance and species composition of oligochaete worms. This is the proposed measure for the indicator. Oligochaete abundances vary directly with the degree of organic enrichment.

The Great Lakes National Program Office (GLNPO) of the U.S. Environmental Protection Agency has also recognized the importance of benthic indicator organisms in the evaluation of the Great Lakes. In 1997 a benthic invertebrate monitoring program was initiated that encompassed all five Lakes, with plans for biological, physical and chemical data to be collected from a minimum of 45 stations on an annual basis.

Figure 6 illustrates the results of the 1997 benthic community monitoring. GLNPO found maximum numbers of species ranging from 10 - 15 per site, with Lake Huron and Lake Ontario having the greatest species richness. As in the 1991-1993 Environment Canada study, GLNPO found the amphipod *Diporeia hoyi* most abundant, with the exceptions of Lake Erie and parts of Lake Ontario where oligochaetes were dominant.

The baseline benthic community data collected in the 1990s through these and other studies will facilitate future reporting on trends and status of the Great Lakes benthic community.

The state of the benthic community was summarized in the Nearshore Waters background paper accompanying the State of the Great Lakes 1997 report,

> "Benthic community structure has generally improved over broad areas in the nearshore zone within the past few decades. Diversity has increased, and forms considered to be pollution-sensitive have become more dominant. Degraded communities are still evident, however, in many local harbours and bays. Broad changes in communities reflect an improved trophic status resulting from abatement programs that were in place before the establishment of the zebra mussel. Large numbers of zebra mussels now present in the nearshore zone have also brought about broad changes in benthic community structure. Many of these changes resemble those resulting from abatement programs. The challenge for the future is to interpret benthic community changes relative to the appropriate causative agent".

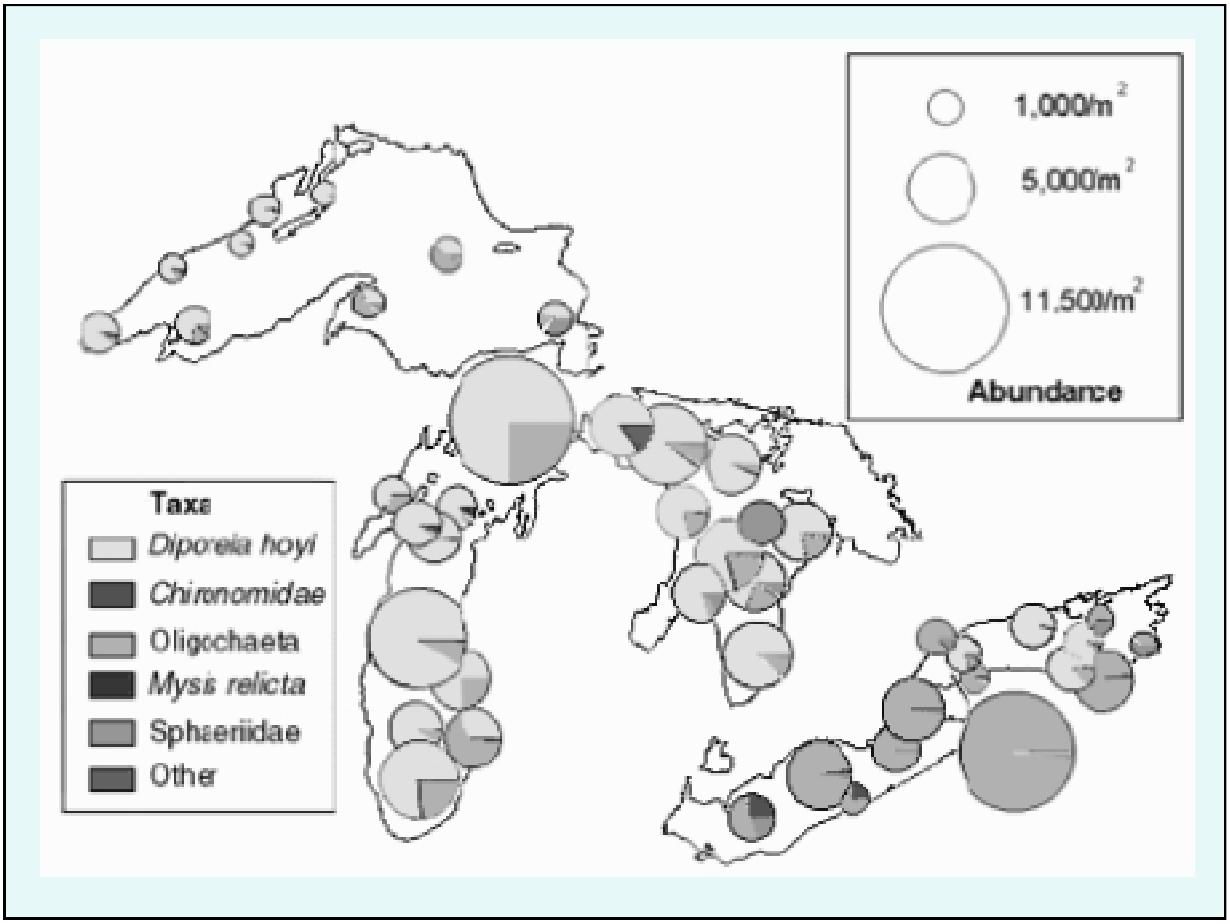


Figure 6. Results of Great Lakes National Program Office 1997 Summer Benthic Monitoring.
Source: Great Lakes National Program Office, U.S. Environmental Protection Agency, 1998.

Phosphorus Concentrations and Loadings

Pressure Indicator (111)

Phosphorus is an essential element for all organisms and is often the limiting factor for plant growth in aquatic ecosystems such as the Great Lakes. Although phosphorus is found naturally in tributaries and run-off waters, the historical problems have predominately originated from man-made sources. Sewage treatment plant effluent, agricultural run-off and industrial processes have released high concentrations of phosphorus into the Lakes. Strict phosphorus loading targets implemented in the 1980s have been successful in reducing nutrient concentrations in the lakes, although high concentrations still occur locally in embayments and harbours. Phosphorus loads have decreased in part due to conservation tillage, integrated crop management, and improvements made to sewage treatment plants and sewer systems.

This indicator assesses total phosphorus levels in the Great Lakes. Simultaneously, it is hoped that information will be obtained on the overall degradation of the aquatic ecosystem and loss of beneficial uses, and also on human-induced causes of phosphorus loadings. The analysis of phosphorus concentrations in the Great Lakes is ongoing and reliable.

Concentrations of total phosphorus in the open waters of the Great Lakes have remained nearly stable since the mid-1980's. Concentrations in Lakes Superior, Michigan, Huron, and Ontario are at or below expected levels. Observed concentrations in the western basin of Lake Erie continue to fluctuate widely, while those in the central and eastern basins slightly exceed expected concentrations based on annual target loadings of phosphorus (Figure 7).

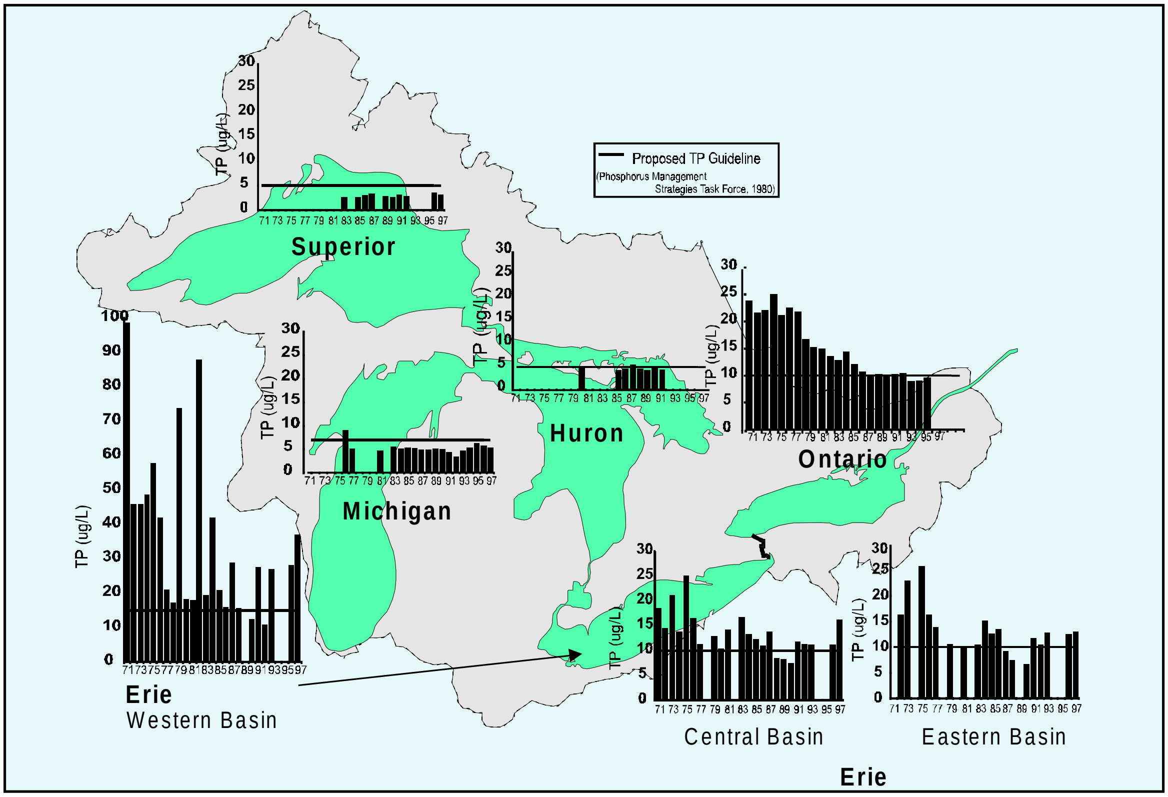


Figure 7. Total Phosphorus Trends in the Great Lakes 1971-1997 (Spring, Open Lake, Surface) (blank indicates no sampling).

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

Contaminants in Colonial Nesting Waterbirds

Pressure Indicator (115)

The Herring Gull egg contaminants monitoring program has produced the longest running, continuous data set for wildlife in the Great Lakes. Each year since 1974, concentrations of 76 organochlorine compounds such as DDT/DDE, PCBs, PCDFs/PCDDs, and periodically some metals, are measured in the eggs of Herring Gulls from sites throughout the Great Lakes (Canada and U.S.) Adult Herring Gulls nest on all the Great Lakes and the connecting channels and remain on the Great Lakes year-round. Because their diet is made up primarily of fish, they are an excellent terrestrial nesting indicator of the aquatic community. The value of the Herring Gull as a chemical indicator will remain, and probably increase, as contaminant levels become harder to measure in water, fish or sediments. Periodically, biological features such as clutch size, eggshell thickness and hatching success of gulls and other colonial waterbirds are also measured. A database of chemical levels and biological measures is available. The data can be used to illustrate temporal trends and geographical patterns, showing all sites relative to one another. Tissues are archived to permit other assessments such as retrospective analyses when new chemicals are identified.

Contaminant concentrations in most colonial-nesting, fish-eating birds are at levels where gross ecological effects such as eggshell thinning, reduced hatching and fledging success and population declines are no longer apparent. Greater reliance for detecting biological effects of contaminants is now being put on physiological and genetic markers.

Contaminant levels in almost all Great Lakes colonial waterbirds are significantly and substantively reduced from what they were 25 years ago. Now, in the 1990s, year-to-year differences in contaminant levels are quite small and detailed statistical analyses are needed to tell if a compound has “stabilized” and is undergoing non-significant fluctuations, or if it is still declining. These analyses show that most contaminants at most sites are continuing to decline at a rate similar to that over the last decade or two. Geographic differences among sites for a given compound are not as dramatic as they once were.

Sites include:

1. St. Lawrence River - Strachan Island (Cornwall)
2. Lake Ontario - Snake Island (Kingston); Toronto Harbour
3. Niagara River - unnamed island 300 m above the Falls
4. Lake Erie - Port Colborne Lighthouse; Middle Island (south of Pelee Island)
5. Detroit River - Fighting Island (LaSalle)
6. Lake Huron - Chantry Island (Southampton), Double Island (Blind River), Channel-Shelter Island (Saginaw Bay, Bay City, Michigan).
7. Lake Michigan - Gull Island (Beaver Islands, northern Lake Mich.), Big Sister Island (Dore Peninsula).
8. Lake Superior - Agawa Rocks (Montreal River), Granite Island (Thunder Bay).

Figure 8 illustrates temporal trends for PCBs in Herring Gull eggs.

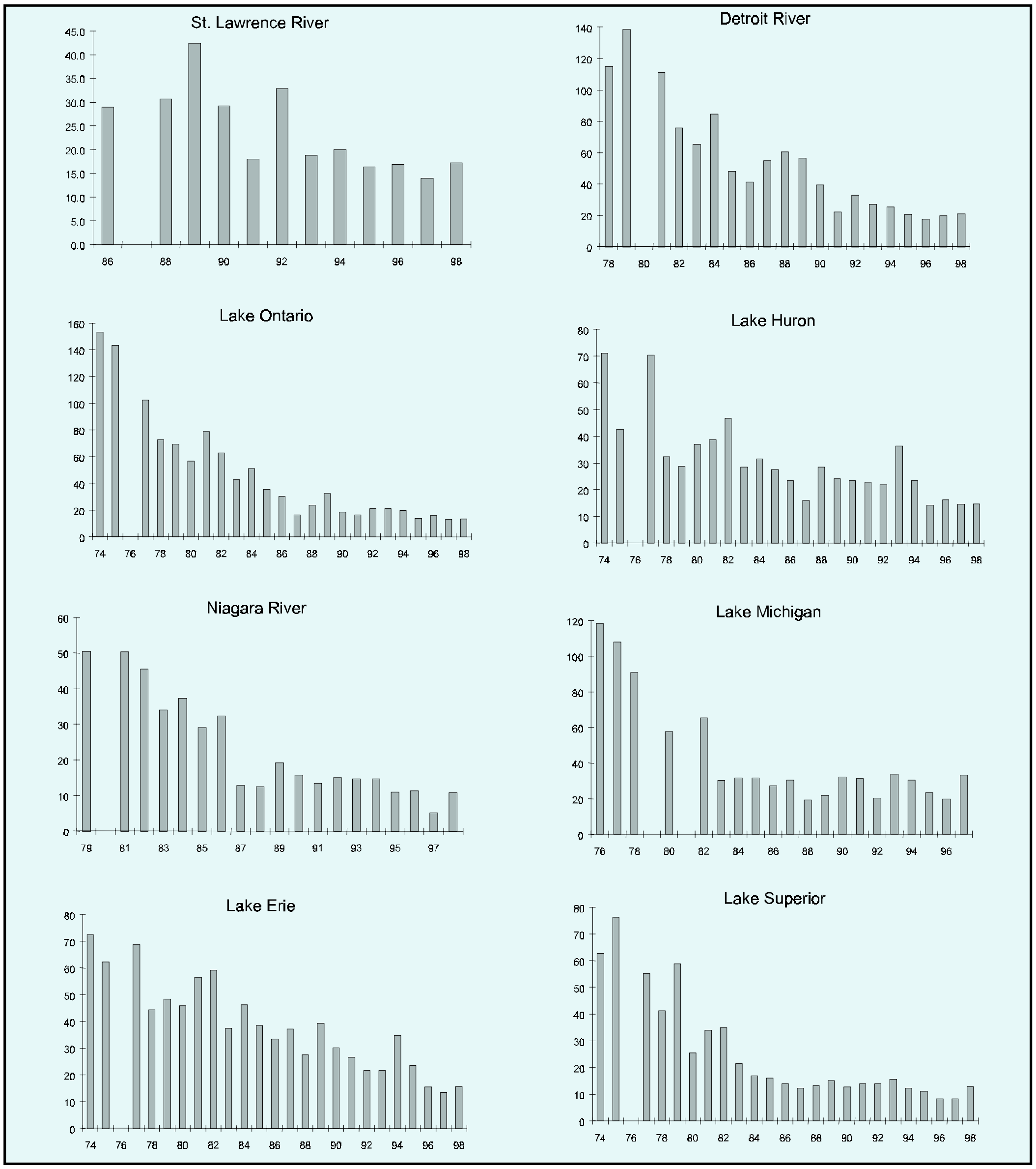


Figure 8. Temporal trends of PCBs (mg/g- wet weight) in Herring Gull eggs from the Great Lakes, 1974-1998.
Source: Canadian Wildlife Service, 1999.

Atmospheric Deposition of Toxic Chemicals

Pressure Indicator (117)

The presence, distribution and cycling of toxic chemicals in the environment is one of the primary concerns of Great Lakes scientists and managers. After initial success with control programs in the late 1970s and early 1980s, a downward trend in contaminants in fish and other biota appears to be levelling out. One explanation was that the continuing contamination was a result of atmospheric deposition.

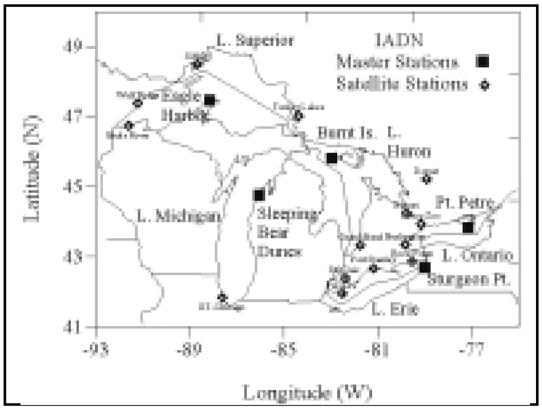


Figure 9. IADN Monitoring Stations located around the Great Lakes Basin.
Source: IADN, 1998.

The Integrated Atmospheric Deposition Network (IADN) was established pursuant to Annex 15 of the Agreement. This is a joint Canada-U.S. network that formally began in January of 1990 to acquire "...sufficient, quality-assured data to estimate with a specified degree of confidence the loading to the Great Lake basin of selected toxic substances". IADN involves a series of monitoring stations on each of the Great Lakes in both Canada and the U.S. (Figure 9).

The IADN measures concentrations of target chemicals in the atmosphere. In order to calculate atmospheric loadings to bodies of water, there are many different things to consider in order to describe the movement of atmospheric contaminants between air and water. In general, an equation is used to determine the wet, dry and gas phase inputs to the water surface minus the amount lost back to the atmosphere. Loadings of pollutants to the lake are a balance of input and output (Figure 10). For some pollutants, there is a net output from the lakes, i.e. the lake is a net source of these pollutants to the atmosphere. If input and output of the gas phase of the pollutants are roughly equal, the atmospheric concentration of the pollutants is said to be in equilibrium with the lakes.

In January of 1998, the governments of Canada and the United States released their Technical Summary of Progress under the Integrated Atmospheric Deposition Program 1990-1996 . Much of the following data are taken from this report and provide an example of the information available through IADN to support this indicator. Monitoring will continue into the future. This indicator will assess the annual average loadings of certain toxic chemicals (including the IJC priority chemicals) from the atmosphere to the Great Lakes.

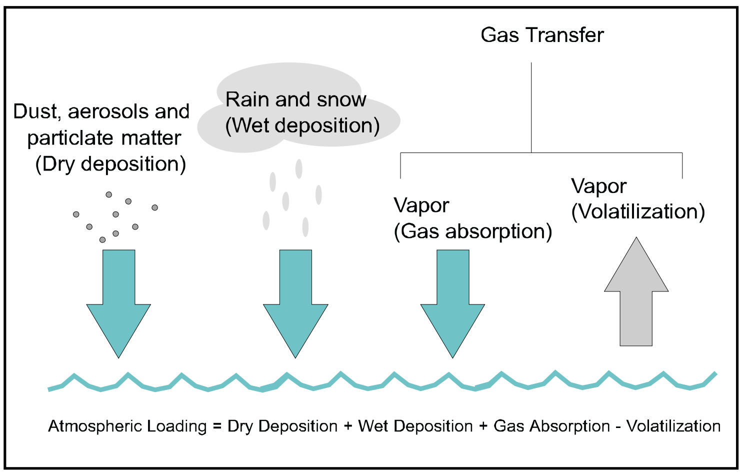


Figure 10. Model used to Estimate the Atmospheric Loadings of Contaminants to the Great Lakes.
Source: IADN, 1999.

Figures 11a-d illustrate long-term spatial and temporal trends in four chemicals. Data are from 1986 to 1994 for one monitoring location in each of Lake Superior (Sibley), Erie (Pelee) and Ontario (Point Petre). Although IADN was not formally initiated until 1990, data are available for these three locations prior to 1990. α-HCH (alpha-Hexachlorocyclohexane), lindane (γ-HCH), β-endosulphan and dieldrin are all organochlorine insecticides that are frequently detected in the environment.

- α-HCH and lindane precipitation concentrations do not show marked differences between monitoring stations, although there has been an overall decline in concentrations over time in all three locations. Lindane sales in Canada have doubled since 1990 possibly resulting in the increase in concentrations seen at the Lake Superior and Lake Ontario stations between 1991 and 1994. Once applied, lindane transforms into the isomer α-HCH. For this reason, increases in α-HCH concentrations may be seen in the future due to the increased application of lindane throughout North America.

- **Dieldrin** concentrations show a general decrease in concentrations with recorded values 3-4 times higher at the Pelee station. The proximity of the station to agricultural activities and increased insecticide usage could explain these higher concentrations.

- **β-Endosulphan** concentrations show no sign of long-term decrease as there has been no restriction on its use as a broad-spectrum insecticide. Levels are generally higher at Pelee Island and substantially higher at Pt. Petre as compared to Sibley.

Detectable insecticide concentrations in the environment vary widely as a result of the physical and chemical properties of the substance, where it is used, how much is used and the weather conditions under which it was applied. Evaporation is an important pathway of pesticide entry into the atmosphere. Depending on the pesticide, 75% or more of what is applied can be lost to the atmosphere over time. Much of this will be returned to the environment through atmospheric deposition causing potentially harmful impacts to fish and wildlife, human health, habitat and water quality.

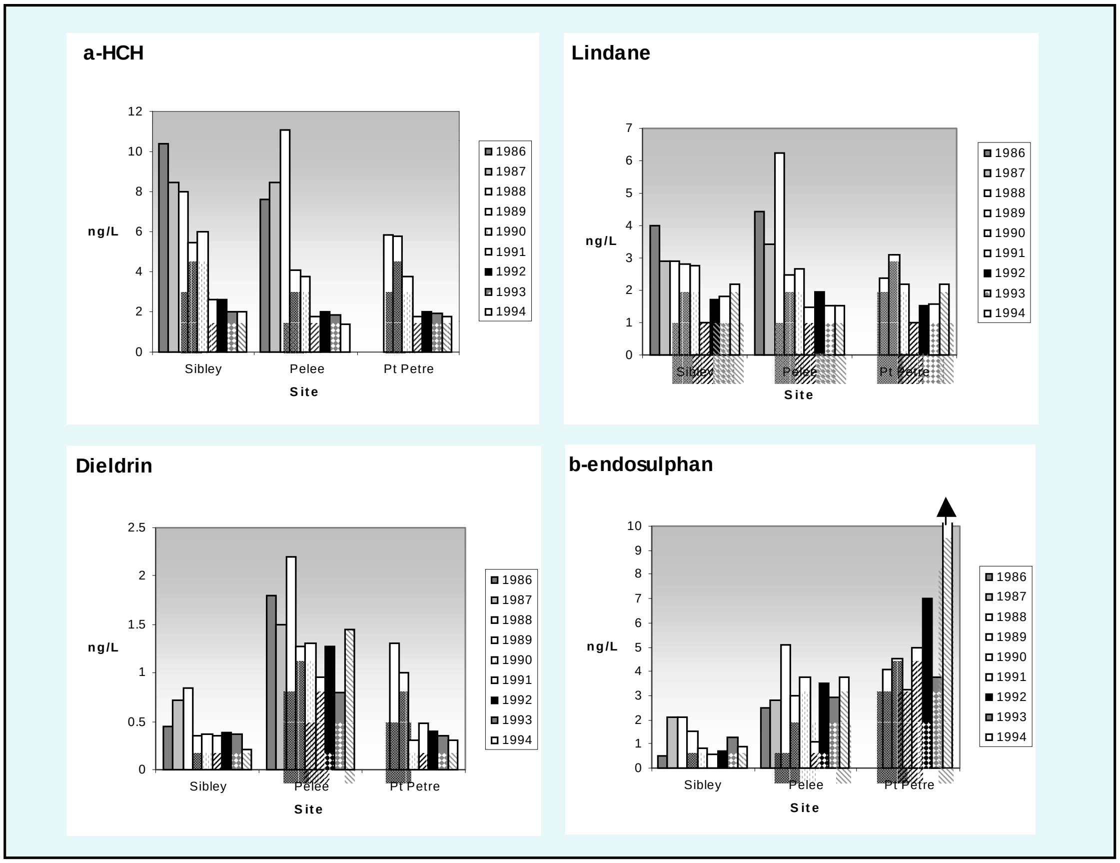


Figure 11a-d. α-HCH, Lindane, Dieldrin and β-endosulphan concentrations found in precipitation at Sibley (Lake Superior), Pelee (Lake Erie) and Point Petre (Lake Ontario). Source: IADN, 1998.

3.1.2 Coastal Wetland Ecosystems

Great Lakes coastal wetlands have formed in shallow, sheltered areas, at the interface between of land and water and can extend up to the 100-year floodline. They range from narrow bands to expansive wetland complexes, shaped by waves, wind tides, seiches, and especially the seasonal and long-term fluctuations in Lake levels.

Wetlands are important ecologically, socially, and economically, and are one of the most productive ecosystems in the world. Wetland plant and animal communities are not only adapted to life on the edge of the terrestrial and aquatic zones, they depend on it and on lake level fluctuations for their continued survival. The social and economic importance includes storm protection, nutrient removal and storage, nursery areas for fish, and recreation.

Despite these values, coastal wetlands are in trouble. Threats include:

- Regulation of lake water levels. Coastal wetlands exist because of water level changes, with a landward shift during periods of high water levels, and a lakeward shift during low water periods. Regulation decreases both wetland extent and diversity in the long term.
- Land use change. Wetlands can be directly removed by shoreline development, or indirectly lost by alteration of the natural sediment supply and transport through land use change either at the shore or in the watershed. If sediments needed to maintain barrier beaches and sand spits are cut off, sheltered wetlands can be exposed to wave attack. Conversely, excess sediments deposited into wetlands significantly reduce germination of many wetland plants, degrade fish habitat and ultimately, can fill in wetlands.
- Exotic species. Species such as carp and purple loosestrife have greatly impacted the ecological balance of many wetland communities.
- Toxic chemicals. Chemicals deposited in coastal wetlands can accumulate as they move up the food chain, becoming most harmful to animals at the top of the food chain, including humans.

To select indicators of the health and integrity of coastal wetlands, the following criteria for coastal wetland health were used:

- capability to self-maintain assemblages of organisms that have a composition and functional organization comparable to natural habitat;
- resiliency to natural disturbances; and
- risk factors or human-induced pressures at an “acceptable level”.

There are few existing monitoring programs for Great Lakes coastal wetlands. Efforts were made to select indicators for which there are existing data and monitoring programs, although many of the indicators will require new or improved monitoring programs.

Wetland-Dependent Bird Diversity and Abundance

State Indicator (4507)

Birds are among the most visible and diverse groups of wildlife in coastal Great Lakes wetlands. Because breeding wetland birds require an appropriate mix and density of vegetation, sufficient and safe food resources, and freedom from predation and other disturbances, their presence and abundance provides information that integrates the physical, chemical and biological status of their habitats. The recent growth in nature-oriented recreation, particularly the sport of birding, has helped develop strong natural history and identification skills in a large proportion of the basin's citizens. The connections between wetland functions and breeding birds, and the potential for involving skilled citizens in monitoring, present an important opportunity to gather information on the health of coastal Great Lakes wetlands.

The Marsh Monitoring Program (MMP) is a bi-national, long-term monitoring program that coordinates volunteers in annual surveys of breeding birds and amphibians of coastal and inland emergent wetlands (i.e. marshes) of the Great Lakes. The program's objectives are to: monitor marsh birds and amphibians at large spatial and temporal scales, contribute to understanding habitat associations of marsh birds and amphibians, and help in the assessment of recovery in Areas of Concern. Volunteers apply standardized methods and conduct bird surveys twice annually at permanent stations along wetland edges and report annually on the vegetation and other habitat characteristics at each station. The MMP is delivered by Bird Studies Canada (formerly Long Point Bird Observatory) in partnership with Environment Canada and with support from the U.S. EPA's Great Lakes National Program Office and Lake Erie Team, and the Great Lakes Protection Fund. After one year of protocol development and field testing, the bird survey component of the MMP was initiated in Ontario in 1994; the program expanded to the entire Great Lakes basin and a calling amphibian survey was added in 1995. Since that time, the program has involved approximately 300 volunteers annually, with surveys established broadly throughout the basin.

For more information on the MMP visit the Bird Studies Canada web site www.bsc-eoc.org

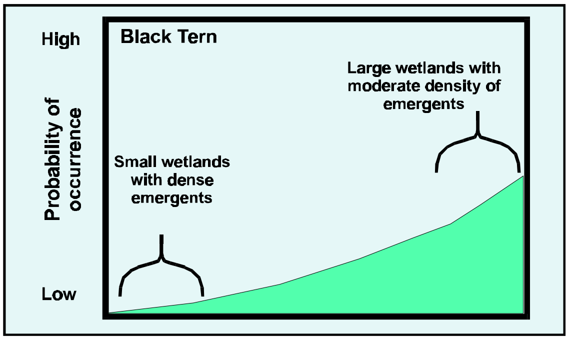


Figure 12. Probability of Black Tern Occurrence in Wetlands of Various Sizes and Different Emergent Vegetation Density.
Source: Canadian Wildlife Service, Environment Canada

Patterns in the species composition and numbers of breeding wetland birds may reflect changes in the condition of breeding habitats. Five years of MMP monitoring data is expected to provide sufficient resolution to identify trends in numbers of marsh nesting birds, including those in Table 1. When combined with an analysis of habitat characteristics such as those summarized in Figure 12, trends in species abundance and diversity can contribute to an assessment of the ability

Table 1. Examples of Projected Detectable Annual Change in Numbers of Marsh Nesting Species

Example of Species/Group	Detectable annual change in numbers (projected)*
Black Tern	4%
Marsh Wren	3%
Virginia Rail	3%
Number of marsh nesting species	1%

*With 100 MMP routes surveyed for five years

of Great Lakes coastal wetlands to support birds and other wetland dependent wildlife. When analyzed at various spatial scales, MMP data can help assess the status of marsh birds and their habitats across regions, individual lake basins or over the whole Great Lakes basin (Figure 12). The use of this indicator to assess Great Lakes wetlands health will be illustrated at SOLEC 2000 through a summary of trends in marsh bird abundance and species composition.

Providing the habitat quality and quantity necessary to sustain breeding populations of wetland-dependent birds across their historical range is an important target for efforts to conserve and restore Great Lakes coastal wetlands. Monitoring the richness and abundance of marsh bird communities is critical to achieving this objective and makes a strong contribution to the overall assessment of Great Lakes wetland health. The MMP provides a large-scale, bi-national, and volunteer-based foundation for this monitoring. With the continued cooperation of agencies, non-governmental organizations and citizen naturalists from across the basin, additional years of data will strengthen the contribution of this indicator to assessments of Great Lakes wetlands.

Example of Future Reporting - the Black Tern, a Population in Decline

While some breeding bird populations are thriving throughout the basin, others are experiencing decline. One such species is the marsh-nesting Black Tern. The Black Tern is still considered locally common in some areas, although its range has declined significantly over the past decades. It is currently considered endangered in Pennsylvania, Ohio and New York, threatened in Ontario, and a species of special concern in Michigan.

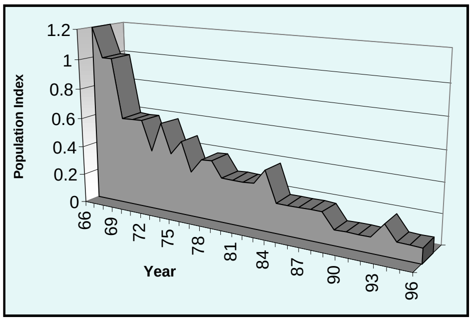


Figure 13. Black Tern Population Trends in the Great Lakes Area 1966-1996.
Source: Breeding Bird Survey, 1996.

The MMP is collecting data on marsh birds in order to look at trends in the various species. While the MMP is still in its early stages, and data are inadequate to determine significant trends, their surveys found that the tern was only recorded in 65 of the 273 MMP routes surveyed in 1995 and/or 1996.

Until the MMP has a more extensive data collection, we can examine trends found in the continental Breeding Bird Survey (BBS). The BBS reports that the Black Tern population has been declining by an average of 4.7% per year since 1966, or an overall loss of 75% of the population (Figure 13). Other wetland bird species are also experiencing declining populations such as the American Bittern as seen in Figure 14.

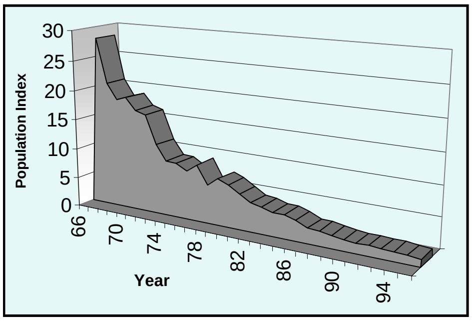


Figure 14. American Bittern Population Trends in the Great Lakes Area 1966-1996.
Source: Breeding Bird Survey, 1996.

The exact reasons for decline are not known, but habitat loss in coastal marshes is an important issue. The Black Tern nests in marshes that have the right ratio of open water to emergent vegetation, usually about 50 / 50. Extreme changes in Great Lakes water levels can significantly influence the proportion of the two habitats in coastal wetlands. Another possible cause for the decline is the continued use of DDT in the Black Tern's wintering grounds in Latin America.

Population Index:
The population indices displayed in this indicator are based on the methods of the Breeding Bird Survey analysis.
For more information:
http://www.mbr-pwrc.usgs.gov/bbs/

Gain in Restored Wetland Area by Type

State Indicator (4511)

This indicator was chosen to measure the success of rehabilitation efforts across the basin. With extensive areas of coastal wetlands lost each year as a result of various threats, it is important to track where and to what extent efforts have been made to create additional wetlands, or rehabilitate lost or seriously degraded wetland area. Another indicator in the suite, Coastal Wetland Area by Type, will address the total loss (or gain) of coastal wetland area in the Great Lakes basin. The area, quality and type of restored wetlands is important. Current information presents rehabilitation effort for wetlands in the whole basin, distinguishing neither coastal ones, nor wetland types, nor enhancements of existing wetland areas from 'new' restored area. These distinctions should be monitored and separated from changes in wetland area and type caused by natural water level fluctuations.

From April 1994 through May 1999, projects to rehabilitate or create more than 2,500 hectares of wetlands have been completed in the Canadian Great Lakes basin, with an additional 1,340 hectares in progress.

The Great Lakes Wetlands Conservation Action Plan (GLWCAP) is a Canadian program of federal and provincial governments as well as non-governmental organizations with a common goal to create, reclaim, rehabilitate and protect wetland habitat in the lower Great Lakes basin. One of the aims of this program is to rehabilitate or create 6,000 hectares of wetland by the year 2001.

The following are some of the projects and programs occurring around the U.S. Great Lakes.

- The U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, U.S. Coast Guard and the Michigan departments of Natural Resources and Environmental Quality recently participated in a multi-agency winter navigation agreement that will protect the St. Marys River and more than 13,300 acres of Michigan's coastal wetlands. In the agreement, there are provisions to protect more than 75 miles of riverine habitat and wetlands from the effects of the early navigation season.

- Through partnerships, the Michigan Private Lands Office has completed 22 wetland restorations totaling 160 acres. The Michigan Wildlife Habitat Foundation, through a cooperative agreement, completed the bulk of these restorations with additional restorations completed through the Kalamazoo Conservation district. Partners, including landowners, contributed approximately 50 percent of the cost of the projects.

- Nearly 11,000 acres of wetlands have been restored through the U.S. Department of Agriculture Wetlands Reserve Program in the Great Lakes watershed within Wisconsin. These 126 sites are long-term restorations or permanent easements, providing flood control, improved water quality, and wildlife habitat in the North American Flyway.

Restoration of Metzger Marsh

Metzger Marsh is a 367-hectare wetland in an embayment in western Lake Erie near Toledo, Ohio managed as a refuge by the U.S. Fish and Wildlife Service and the Ohio Division of Wildlife. The embayment was formerly protected from waves on the lake by a barrier beach that was lost to erosion during high lake levels in 1973. Progressive loss of vegetated area accompanied erosion of the protective barrier. Therefore, the management agencies opted for an active restoration program that incorporated a dike to mimic the protective function of the lost barrier beach but included a water-control structure that could be opened following restoration to allow hydrologic connection with the lake. After the dike was constructed, the control structure remained closed for two years to allow a drawdown of water levels to mimic a low lake-level period. The seed bank produced a quick response in revegetating the wetland. The wetland was reflooded in 1998, and the control structure will be opened in 1999. The control structure also contains an experimental fish-control system that will allow direct wetland access by most fish, yet restrict access by large carp.

Cootes Paradise Marsh, Hamilton, Ontario, Canada

Internet address for the project: http://www.mcmaster.ca/ecowise

Cootes Paradise is a 250 hectare marsh at the west end of Lake Ontario. The marsh watershed supports over 500,000 people including the cities of Hamilton and Burlington. Since 1934 emergent vegetation cover in this once thriving and diverse wetland has decreased by 85% leaving largely cattails and manna grass. High water levels, the regulation of Lake Ontario, excessive nutrients, and high turbidity are some of the factors that are thought to be responsible for this loss of wetland area and biodiversity. Despite the degradation of the marsh, it is classified as a Class 1 Provincially Significant Wetland, and an Area of Natural and Scientific Interest among numerous other designations.

A goal of the Hamilton Harbour Remedial Action Plan, is to restore Cootes Paradise. Point-source inputs of nutrients from the three main tributaries, four combined sewer overflows and a local sewage treatment plant will be reduced. A barrier/fishway was built to prevent large carp from entering Cootes Paradise from Hamilton Harbour.

With the help of hundreds of volunteers of all ages, numerous planting sessions were held in the summers of 1993 and 1994 using over 10,000 plants grown by students in local schools.

By 1999, 200 hectares of vegetation in the marsh have been restored. Ninety percent is submergent vegetation, including wild celery which has not been seen in the marsh in 50 years. The other 10 percent is emergent vegetation. Other improvements include higher plant densities, improved water clarity especially in the spring, and the return of Common Moorhen, Pied-Billed Grebe, Bullfrog and the Northern Spring Peeper.

Sediment Flowing into Coastal Wetlands

Pressure Indicator (4516)

A major stressor affecting coastal wetlands is change in the location and movement of sediments. Where sediments feed barrier beaches and sand spits that protect wetlands, sediment reduction can shrink protection barriers and expose wetlands to wave attack. If excess sediments are deposited into existing wetlands, they can bury submergent vegetation and affect fish spawning and other functions. As little as 0.25 centimetres deposition of excess sediment can have a significant effect on the germination of many wetland plant species.

Human activities in the Great Lakes basin have substantially altered the amount and particle size of sediments flowing into the Great Lakes. Increased sediment loads entering coastal wetlands are largely due to changes in land use in the upstream watersheds. Changes include reduction of vegetated cover, increased agricultural runoff, urbanization, construction, and logging activities.

Because much of the sediment load originates in agricultural areas, sediments can carry high loads of nutrients, pesticides and other farm chemicals. High sediment concentrations cause turbidity which reduces the light reaching submergent vegetation and phytoplankton and limits plant growth.

The SOLEC 96 background paper Coastal Wetlands of the Great Lakes reported that severe sediment loading is extensive throughout the lower lakes where agricultural activity and urbanization are common, but is more localized in the upper lakes.

For many years the U.S. Geological Survey and Environment Canada have monitored sediment yields from numerous Great Lakes tributary watersheds including many associated with coastal wetlands. This provides an accessible data source. Figure 15 illustrates estimates of sediment yields from monitored Lake St. Clair coastal wetland watersheds (Canadian) between 1990 and 1996. In this case, higher yields indicate a greater human-induced pressure on the associated coastal wetlands but all years are high relative to rates for other Great Lakes wetland watersheds. The St. Clair watersheds support intensive agriculture. Information on land use changes in the watershed is needed before annual changes in sediment loads yields can be related to changes in land use patterns. The higher sediment yields in some years correspond to higher rainfall years. With climatologists suggesting that climate change might include more frequent highly erosive storms, future reduction of sediment yield from agricultural areas could be an even greater challenge than it is today.

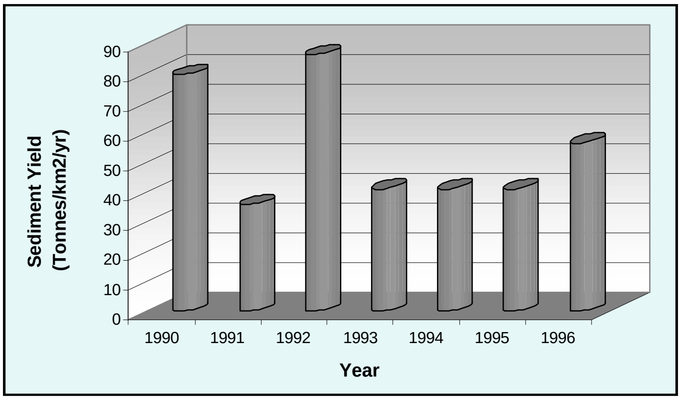


Figure 15. Sediment Yield from Monitored Coastal Wetland Watersheds: Lake St. Clair (Canadian Side).

3.1.3 Nearshore Terrestrial Ecosystems

The nearshore terrestrial environment or the "land by the Lakes" is an integral part of the Great Lakes ecosystem, the extent of which is defined by the Lakes themselves. As with all ecosystems, they have a physical component, living biological communities and the processes that support them. In general terms, the lands within about one kilometre from the Great Lakes shoreline are included in this category.

While the dynamic lakeshore provides ideal conditions for diverse plant and animal communities and habitats, it is also the focal point for human settlement, industry and recreation. This inevitably causes major stresses on these natural communities. In the State of the Great Lakes (1997), a rough assessment was made of how well the nearshore terrestrial environment was doing by looking at the health of 17 Great Lakes coastal ecoregions, 12 special Great Lakes ecological communities and the overall nearshore terrestrial ecosystem health of each Lake. The conclusion was that the health of the nearshore environment was degrading throughout the Great Lakes. It is still degrading today. More information can be found in the SOLEC 96 background report – The Land by the Lakes, Nearshore Terrestrial Ecosystems.

Thirteen indicators of nearshore terrestrial ecosystem health have been developed to fulfil the need for a cost-effective and easily understood set of measures that will tell us how nearshore ecosystems across the basin are changing, what is causing the changes, the current status of these ecosystems and component parts, and how effectively humans are responding to the changes. One of those indicators provides information for each of 12 special lakeshore communities.

Area, Quality and Protection of Special Lakeshore Communities

State Indicator (8129)

The twelve special lakeshore communities presented in this indicator are some of the most ecologically significant habitats in the terrestrial nearshore. The twelve special lakeshore communities are:

- sand beaches;
- sand dunes;
- bedrock and cobble beaches;
- unconsolidated shore bluffs;
- coastal gneissic rocklands;
- limestone cliffs and talus slopes;
- lakeplain prairies;
- sand barrens;
- arctic-alpine disjunct communities;
- Atlantic coastal plain disjunct communities;
- shoreline alvars; and,
- islands.

The indicator was designed to measure the area, quality, and protected status of these twelve special lakeshore communities occurring within one kilometre of the shoreline. The information collected to satisfy this measure may also help to identify the sources of threats to some of the most ecologically significant habitats in the Great Lakes terrestrial nearshore, as well as the success of management activities associated with the protection status.

In order to thoroughly track changes in this indicator, a baseline of the area of each of the twelve special lakeshore communities will need to be established for comparison with periodic monitoring every three to five years. Unfortunately, data collection may be difficult because of the large area and the number of different jurisdictions. In addition, information on location and quality for some special lakeshore communities is incomplete, therefore, this indicator will require some expense and time to establish a reliable baseline.

An example of one of the communities (sand dunes) can be explored to show the kinds of data that will be required for all 12 communities.

Area, Quality and Protection of Sand Dunes

Sand dunes form where sand grains from one-sixteenth to two millimetres in size are abundant, wind blows frequently, and there is a place for sand to be deposited. Over time, dunes actively move. The major stress on this community is habitat alteration which is caused by blowouts, sand mining, primary and second-home development, and recreational impacts. The health of this community was rated D in the State of the Great Lakes (1997) report and was considered moderately degrading. It is not likely that this rating has changed significantly since that time. Several of the 20 Nearshore Terrestrial Biodiversity Investment Areas proposed in a background report to the State of the Great Lakes (1997) report include sand dune landscapes which may be a future protection measure for these fragile communities. For further information on BIAs see Chapter 4 or visit one of the SOLEC websites — www.epa.gov/glnpo/solec/98/ or www.cciw.ca/solec/.

As shown in Figures 16-18, there are numerous ways to illustrate this indicator including: a simple map of the location and extent of sand dunes; the percent of sand dune communities included within areas formally managed for conservation at various levels; or a summary of quality rankings for special natural communities such as dunes, based on such criteria as the

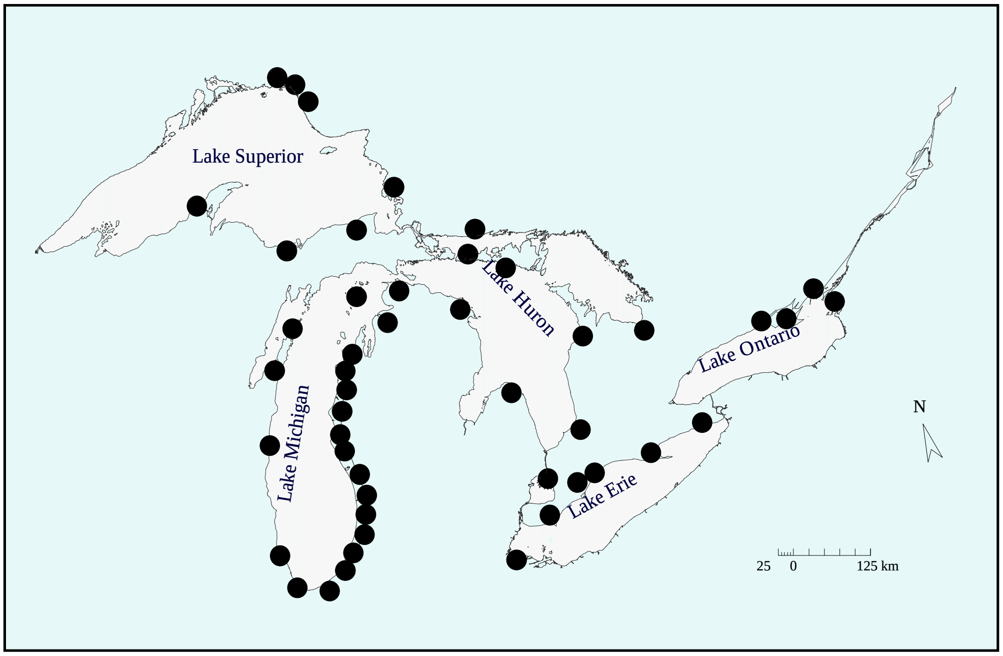


Figure 16. Sand Dune Complexes in the Great Lakes Basin.

US EPA ARCHIVE DOCUMENT

size and viability of each occurrence and the integrity of the surrounding landscape. These figures are based on preliminary data and are provided primarily to give an idea of how this indicator will look when complete data are available.

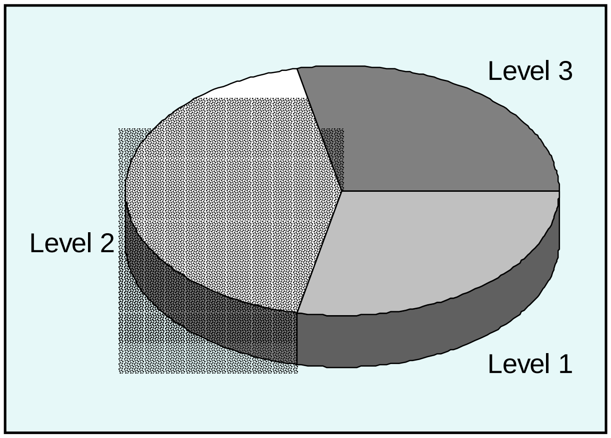


Figure 17. Level of Protection Provided to Sand Dune Complexes within Managed Areas.

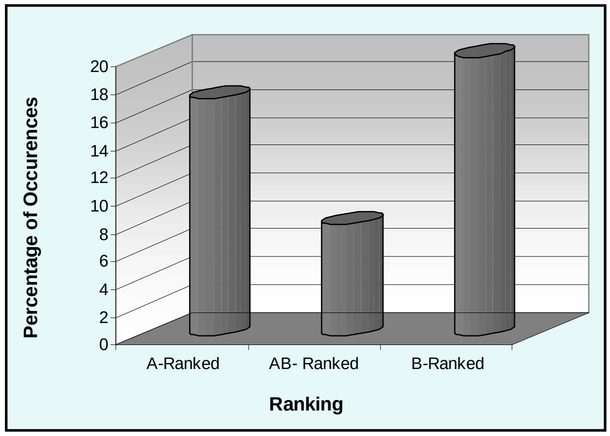


Figure 18. Quality of Sand Dune Complexes in the Great Lakes Basin.

Working Towards Dune Protection
The Ontario Dune Coalition

The Ontario Dune Coalition has one main concern: the stabilization of dunes on the eastern shore of Lake Ontario. The more than 30 organizations who are members have several objectives. First, they assist in stabilizing the dunes as natural systems. Second, they are developing measures to maintain dune stability. Finally, they hope to encourage public use which is in keeping with their dune protection goals.

For more than a dozen years the members of the Ontario Dune Coalition have been working to stabilize, restore and protect the dunes of eastern Lake Ontario. By improving access for the public, educating users, providing technical assistance, and coordinating research, the dunes have not disappeared. They are healthier and richer ecologically and as a consequence, enjoyed and appreciated by more people each year.

The Coalition's activities are numerous and varied. One private landowner is growing a native beachgrass to be used in dune restorations. Dune stewards walk the dunes, greeting visitors and helping them to understand the importance of staying on trails and telling stories about dune animals and plants. Brochures and interpretive signs inform visitors about dune and wetland ecology. Walkovers and boardwalks have been constructed to limit access to newly vegetated and sensitive dunes. All activities are designed to decrease visitor impacts in sensitive areas while improving access to the beaches.

3.1.4 Land Use

Changing patterns of land use are a major ecosystem stressor for the Great Lakes basin and its nearshore areas. The five Great Lakes themselves and the connecting channels account for approximately one-third of the total area covered by the basin with various land use classes making up the remainder. Forests account for the largest percentage of total basin area, at about 40%. Agriculture accounts for about 25% of present basin area, and the "built environment"— representing industrial, commercial, residential, institutional, and transportation uses—takes up less than 3% of the area of the Great Lakes basin. These numbers are not static, fluctuating with changing patterns of land use. Although natural forces have the greatest potential for altering landscapes and land cover, the current human imprint on the land in the Great Lakes area is obvious and substantial. Human activities ranging from farming to urban development are affecting the basin's ecosystem.

The many forms of development—including industrial, commercial, residential, agricultural, and transportation-related activities—carry specific, significant, and cumulative impacts for the natural world and particularly for Great Lakes water quality. These activities take place throughout the basin, but their most immediate and direct impact on the Great Lakes appears to be on lands proximate to the Lakes themselves and their tributary waters. These nearshore areas suffer from a particular and disproportionate environmental burden because of their unique and sensitive environments and proximity to development. Land use in coastal areas of the Great Lakes is changing in response to the region's evolving economy and industrial restructuring as well as to the relentless forces of urban sprawl. The aesthetic and recreational attraction of the shores is also spurring renewed public appreciation and use of this asset, whether it be an urban waterfront or a remote location.

Sustainable Agricultural Practices

Human Activity Indicator (7028)

Ontario Activities

Our Farm Environmental Agenda was released by the Ontario Farm Environmental Coalition (OFEC) in January of 1992. The Coalition was formed to enable farm groups to deal better with political challenges and take control of their environmental agenda. Government ministries, agencies, non-government organizations and farm groups devoted thousands of hours of time developing an Environmental Farm Management Plan (EFP) program in the early 1990s. The farm plan is a process that starts with a workshop on environmental farm issues and culminates in a completed plan of remedial actions that are eligible for limited grant funding. The program is voluntary and of the over 50,000 farmers in Ontario that are eligible it is hoped that most will participate in the process to raise awareness and enhance the role of farmers as stewards of the land.

Farmers complete a farm plan identifying environmental areas of concerns on their farms with activities and specific actions that will be taken to remediate these. For example, ensuring that farm manure is managed to avoid contaminating surface water courses and groundwater is critical to safe and clean drinking water for the farmer as well as preventing contamination of downstream water or aquifers. The farm plan will identify the possibility of contamination and identify preventative or remedial solutions and actions.

Farmers are eligible for grants up to $1,500.00 (Can) to assist them in delivering the specified environmental remedial actions in their farm plans, once their plan has been reviewed and approved. The farm plan then becomes a stewardship guidebook for environmental management by the farmer and a reference document for further remedial or preventative actions.

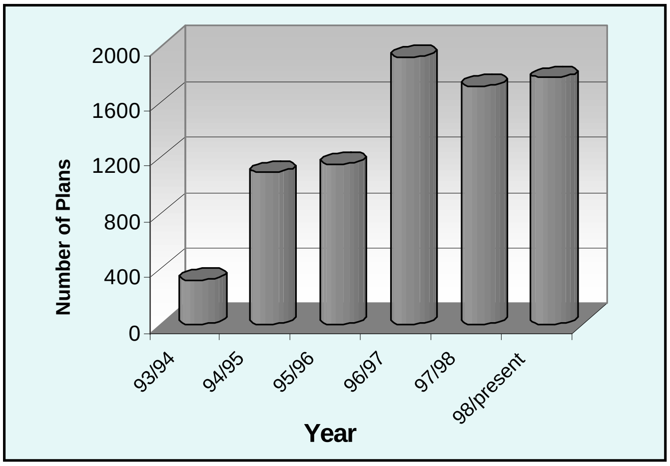


Figure 19. Number of Environmental Farm Plans Approved in Ontario 1993-1999.
Source: Ontario Soil and Crop Improvement Association.

Program Results
From 1993 to April 1999, there have been over 1,000 workshops held for farmers, involving almost 15,000 or a third of Ontario's farmers leading to the approval of 7,892 farm plans. Environmental Farm Plan workshops continue to be well attended and in the last several years have exceeded projected attendance. Figure 19 depicts the number of approved Environmental Farm Plans in Ontario.

United States Activities

The U.S. Department of Agriculture (USDA) offers landowners financial, technical, and educational assistance to implement conservation practices on privately owned land, and to promote sustainable agricultural practices. The following are brief overviews of some of the cost-share programs managed by USDA.

Conservation Reserve Program
The Conservation Reserve Program (CRP) reduces soil erosion, protects the Nation's ability to produce food and fiber, reduces sedimentation in streams and lakes, improves water quality, establishes wildlife habitat, and enhances forest and wetland resources. It encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as tame or native grasses, wildlife plantings, trees, filterstrips, or riparian buffers. Farmers receive an annual rental payment for the term of the multi-year contract. Cost sharing is provided to establish the vegetative cover practices. As of June, 1998, 23,350 agreements were in place in the U.S. Great Lakes basin counties affecting nearly 810,000 acres (Table 2).

Table 2. Conservation Reserve Program contracts issued and acres affected in U.S. Great Lakes basin counties, as of June, 1998.

State	CRP Acres	CRP Contracts
Illinois	None in GL watershed	None in GL watershed
Indiana	118,402	3,944
Michigan	284,452	3,927
Minnesota	796	42
New York	50,733	1,487
Ohio	175,683	6,592
Pennsylvania	4,840	140
Wisconsin	174,755	7,236
Total	809,661	23,350

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) works primarily in locally identified conservation priority areas where there are significant problems with natural resources. High priority is given to areas where agricultural improvements will help meet water quality objectives. EQIP offers contracts for conservation practices, such as manure management systems, pest management, erosion control, and other practices to improve and maintain the health of natural resources. Activities must be carried out according to a conservation plan.

Farmland Protection Program

The Farmland Protection Program provides funds to help purchase development rights to keep productive farmland in use. Working through existing programs, USDA joins with State, tribal, or local governments to acquire conservation easements or other interests from landowners. To qualify, farmland must meet several criteria, including having a conservation plan.

Stewardship Incentive Program

The Stewardship Incentive Program provides technical and financial assistance to encourage nonindustrial private forest landowners to keep their lands and natural resources productive and healthy. Eligible landowners must have an approved Forest Stewardship Plan and own 1,000 or fewer acres of qualifying land.

Wetlands Reserve Program

The Wetlands Reserve Program is a voluntary program to restore wetlands. Participating landowners can establish conservation easements of either permanent or 30-year duration or can enter into restoration cost-share agreements where no easement is involved. Restoration cost-share agreements establish wetland protection and restoration as the primary land use for the duration of the agreement. In all instances, landowners continue to control access to their land.

Wildlife Habitat Incentives Program

The Wildlife Habitat Incentives Program provides financial incentives to develop habitat for fish and wildlife on private lands. Participants agree to implement a wildlife habitat development plan. USDA and program participants enter into a cost-share agreement for wildlife habitat development. This agreement generally lasts a minimum of 5 years.

Sustainable Agriculture Research and Education Program

The Sustainable Agriculture Research and Education (SARE) program works to increase knowledge about – and help farmers and ranchers adopt – practices that are economically viable, environmentally sound and socially responsible. To advance such knowledge nationwide, SARE administers a competitive grants program first funded by Congress in 1988.

For the combined years 1997 - 1998, 78 grants were awarded within the eight Great Lakes states. As the outreach arm of SARE, the Sustainable Agriculture Network (SAN) provides national leadership in facilitating information exchanges in support of sustainable agriculture. Information is produced in a variety of formats, including print, World Wide Web, and electronic books, or diskette versions.

Breeding Bird Diversity and Abundance

State Indicator (8150)

The Great Lakes basin supports a rich diversity and abundance of breeding birds making it one of the most important regions on the North American continent for many species. Long-term, comprehensive monitoring of the status and trends of bird populations and communities can allow resource managers to determine the health of bird communities and habitat conditions.

The proposed measure for this indicator is the diversity and abundance of breeding bird populations and communities in selected habitat types, and an index of the biological integrity of the populations. Breeding birds are strongly linked to habitat conditions so this indicator also has potential to have cross applications to other wildlife species and other indicators. Changes in abundance, density, and productivity of breeding birds are caused by many factors both on and off the breeding territories. Care must be used in determining the causes of these changes, especially for birds that spend much of each year on migration or in distant wintering habitats.

This indicator is similar to the Coastal Wetland Bird Diversity and Abundance indicator, but has a much broader scope, thus allowing interpretation at many levels. Population trends of an individual species within a limited geographic area provides useful information to land managers and may suggest specific management activities that should be undertaken. In the future, comparisons of indices of biological integrity among sites would provide a way to evaluate the variety of management strategies employed in similar environmental settings. Analysis of broad patterns, using biodiversity maps provide opportunities to identify landscape level activities that influence ecosystem health.

Until data are collected to support the calculation of these indices of biological integrity, a look at population and distribution trends of breeding bird species found in the basin provides a glimpse into the potential contribution of this indicator to determining the health of the Great Lakes.

Peregrine Falcon - Staging a Comeback

Peregrine falcons were widely distributed throughout the Great Lakes basin before populations dropped drastically in the 1940s and 1950s because of increasing use of DDT across North America. Following the ban on DDT use, a continent wide recovery program was introduced to attempt to bring back the species. Between 1977 and 1996, over 600 peregrines were released in Ontario, and the neighbouring Great Lakes States also released hundreds of individuals. By 1997 there were over 100 confirmed pairs in the Great Lakes States and 21 pairs in Ontario. Today, there are more than 1,600 pairs in the skies throughout Canada and the United States. These data prompted the Committee on the Status of Endangered Wildlife in Canada to improve the status of the *Anatum Peregrine Falcon* to nationally threatened rather than nationally endangered. In August of 1998 the U.S. Department of the Interior proposed to remove the falcon from the Endangered Species List. One year later, on August 20, 1999, the peregrine falcon became the first bird to be removed off the endangered species list in the U.S.

Giant Canada Goose -"Nuisance" Species on the Rise

For several decades prior to 1962, the Giant Canada Goose (*Branta canadensis maxima*) was thought to be extinct. Its rediscovery that year began a rapid restoration of the subspecies throughout its previous range (Figure 20). While many municipalities in the Great Lakes basin now consider this species a nuisance, its restoration is actually considered a success story. The geese are well adapted to living in populated and urbanized areas and goose-human conflicts are increasing. Municipalities request permits and assistance in dealing with the problems incurred by the geese in such areas as parks, golf courses and beaches. The agricultural community is also in need of assistance to prevent the geese from damaging crops.

In response to the high goose populations, regulatory agencies are implementing hunting regulations to increase the kill of Giant Canada Geese, while protecting other subspecies of migrant Canada Geese. Some communities are also getting involved in goose capture and relocation projects, while others are now considering the use of border collies to scare geese from areas such as airport runways and golf courses.

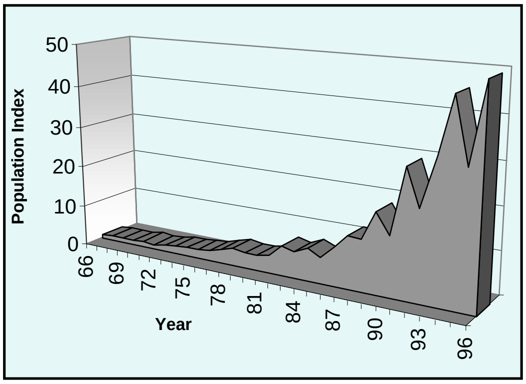


Figure 20. Canada Goose Population Trends in the Great Lakes Area 1966-1996.
Source: Breeding Bird Survey, 1996.

Double Crested Cormorant

The Double Crested Cormorant (*Phalacrocorax auritus*) was near extinction in the 1970s as a result of drastic impacts from toxic chemicals. From 1973 to 1993, however, the cormorant population increased over 300 fold to more than 38,000 pairs (Figure 21). The cormorant is now more numerous on the Great Lakes than at any time in its previously recorded history because of decreases in contaminant releases in the Great Lakes basin and changes in the preyfish populations in the Lakes.

The growth in cormorant populations seen in the early 1990s is no longer evident. It is difficult for a species to maintain such growth rates as resources such as food and habitat become limiting. It is likely that the cormorant populations will stabilize sometime in the future.

Some interest groups in the Great Lakes basin believe that the population of cormorants is having a significant impact on fish populations. Scientists and fish managers suggest that the amount of fish which cormorants consume in eastern Lake Ontario, for example, is posing a serious threat to the sport fishery (as reported in a report released by New York State Department of Environmental Conservation entitled To Assess the Impact of Double-Crested Cormorant Predation on Smallmouth Bass and other Fishes of the Eastern Basin of Lake Ontario). Some individuals have chosen to take control of the rapid cormorant population growth into their own hands. In April of 1999, nine individuals pleaded guilty to inhumanely killing more than 1,000 double-breasted cormorants on Little Galloo Island in the eastern basin of Lake Ontario. The states of New York and Vermont have been granted permission from the U.S. Fish and Wildlife Service to control the double-crested cormorant populations by placing oil on eggs. This limits hatching success.

For more information on the double-crested cormorant, see the U.S. Fish and Wildlife Services' cormorant web page at www.fws.gov/r9mbmo/issues/cormorant/cormorant.html, or the Canadian Wildlife Services' fact sheet at www.cciw.ca//glimr/data/cormorant-fact-sheet/intro.html.

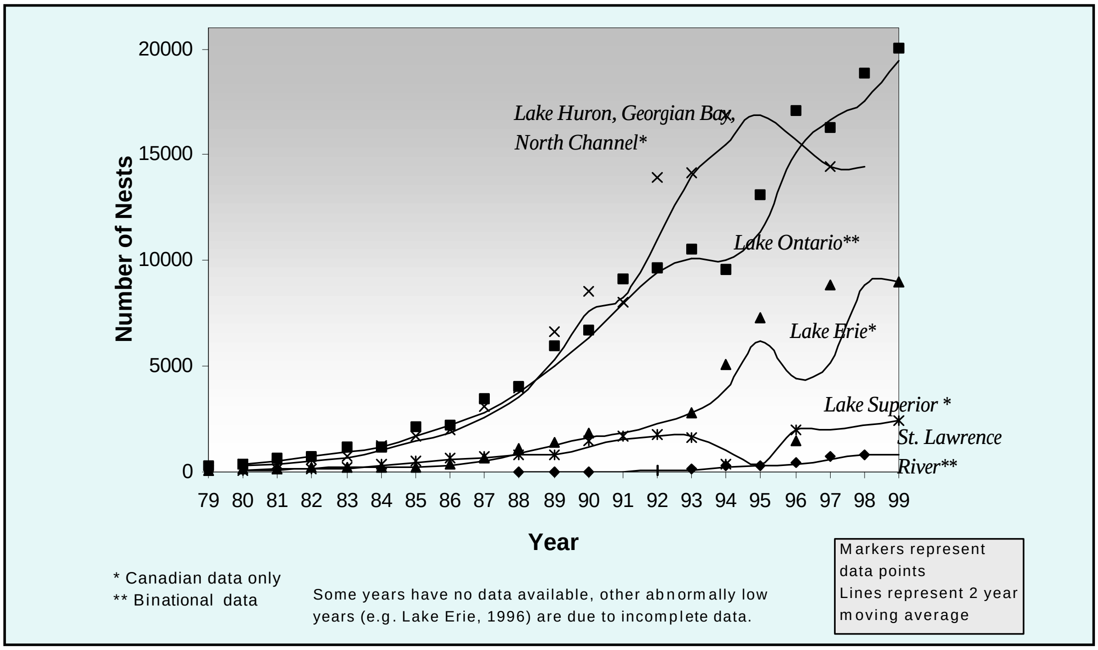


Figure 21. Number of Double-crested Cormorant Nests Found on Lakes Ontario, Erie, Huron and Superior between 1979-1999.
Source: Canadian Wildlife Service, Environment Canada, 1999.

3.1.5 Human Health

Human populations in the Great Lakes basin, as with those living elsewhere, are exposed to many toxic pollutants present in the environment. This reality positions issues dealing with the health of individuals and communities as a continuing priority identified by residents and governments in the Great Lakes basin. In addition, the majority of people consider that protecting human health is one of the more important goals of environmental management. Consequently, there is interest in having indicators for monitoring changes in human health, or changes in factors that affect health, as they relate to the Great Lakes environment. The premise is that as social, economic and environmental conditions change in the Great Lakes basin, so could the health of the population. Such indicators are also needed to assess the effectiveness of social, economic, health and environment policies and actions in protecting or improving the health of the Great Lakes basin population.

For practical purposes, this effort to develop health indicators has focussed primarily on indicators of human exposure to environmental contaminants. The indicators of exposure are either contaminant levels measured in human tissues, such as breast milk or blood, estimates of daily intake of persistent contaminants by the Great Lakes population (e.g. via fish consumption), or contaminant levels in air, drinking water and recreational water. The contribution of these exposures as causative factors in disease, such as cancer and birth defects, can be difficult to identify. However, a different indicator which analyses geographic patterns and trends in incidence rates can serve to identify potential areas of concern and may lead to testable hypotheses regarding the correlation of environmental exposure with human disease. The health indicators presented below focus on human exposure.

Fecal Pollution Levels of Nearshore Recreational Waters

Pressure Indicator (4081)

One of the most important factors in nearshore recreational water quality is that it be free from harmful microbial contamination. Recreational waters may become contaminated with animal and human feces from sources such as combined sewer overflows that occur in certain areas after heavy rains, agricultural run-off, and poorly treated sewage. Gastrointestinal disorders and minor skin, eye, ear, nose and throat infections have been associated with microbial contamination. Human exposure to micro-organisms occurs primarily through ingestion of water and can also occur via the entry of water through the ears, eyes, nose, broken skin, and through contact with the skin. Children, the elderly, and people with weakened immune systems are those most likely to develop illnesses or infections after swimming in polluted water.

This indicator will track *E.coli* and fecal coliform abundance and the frequency of beach closings over time and across geographic locations throughout the basin. Analysis of data may show seasonal and local trends in nearshore recreational waters. The trends provided by this indicator will aid in beach management and in the prediction of episodes of poor water quality.

Figure 22 illustrates one way of presenting this indicator, and is based on measurements of the number of *E. coli* at Ontario public beaches. Guideline exceedances were used to assess whether beaches were impaired from a human health standpoint. Using the geometric mean *E. coli* levels reported for each sampling session, the median, 5th and 95th percentile values were calculated, by beach and by year, for selected

Canadian Great Lakes basin beaches. These summary values were chosen to give a snapshot of overall microbial quality, as well as the range of geometric mean *E. coli* levels experienced during the bathing season.

Median levels for the June 1st to August 31st swimming season for the years 1992 to 1996 for Ontario public beaches generally fall below the Ontario guideline of 100 *E. coli* / 100 ml water. Nonetheless, there are instances where the median value is above the guideline.

As the Great Lakes population grows, there will be increasing pressure on the shoreline by users, and possibly increased microbial pollution. However, pollution controls and remediations such as reducing combined sewer overflows, and improvements in sewage treatment, have improved water quality in some areas of the Great Lakes basin in recent years. The continuation of such efforts will greatly contribute to the improvement of recreational water quality.

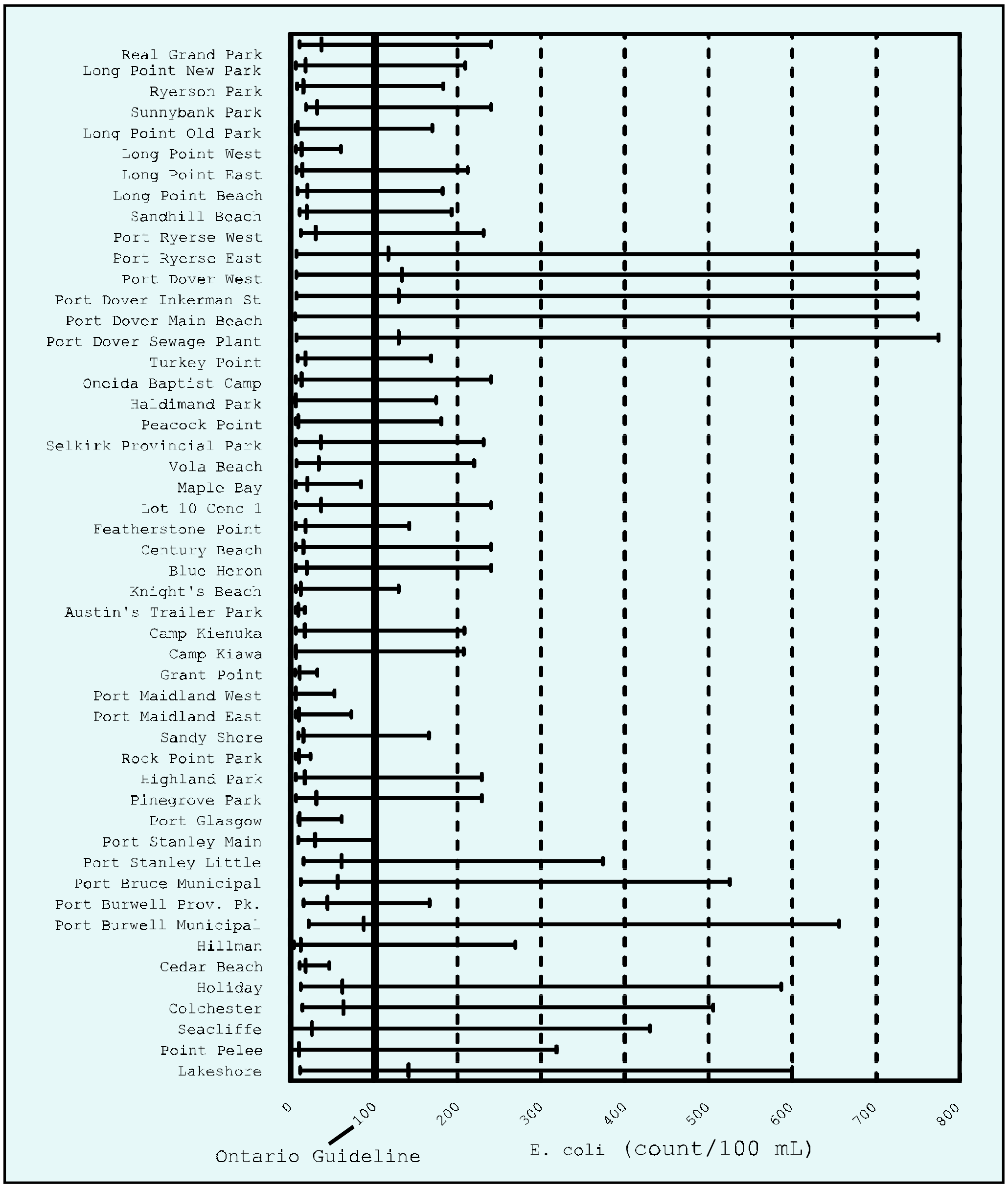


Figure 22. *E. coli* levels at Selected Lake Erie Beaches, 1996 Swimming Season.
Source: Health Canada

Chemical Contaminants in (edible) Fish Tissue

Pressure Indicator (4083)

Monitoring changes in the concentration of contaminants in fish from each Great Lake will allow regulatory agencies to make suggestions regarding remedial planning throughout the basin as well as issue advisories on consumption limits. While the measurement of the concentrations of persistent, bioaccumulative, toxic chemicals (PBT) in fish tissue is a direct measure, this indicator also provides information on the exposure of humans to PBT chemicals through consumption of Great Lakes fish caught via sport and subsistence fishing. The data presented here represent concentrations of chemicals in the whole fish. This gives an indication of trends in PBT in the ecosystem. One can infer human health implications, but clearly data on edible portions are more directly indicative of human health exposure to PBT chemicals and in the future this data will be used for this indicator.

All jurisdictions in the Great Lakes basin collect information on contaminants in sport fish. For example, the current Guide to Eating Ontario Sport Fish, released in the spring of 1999, shows that there are five contaminants or groups of contaminants responsible for fish consumption advisories. These include mercury, PCBs, mirex/ photomirex, toxaphene and dioxins. Figure 23 shows the percentage of consumption restrictions based on each of the groups of contaminants in the four Ontario Great Lakes, Lake St. Clair and the connecting channels. In the future, reports using this indicator will include other jurisdictions' fish consumption information.

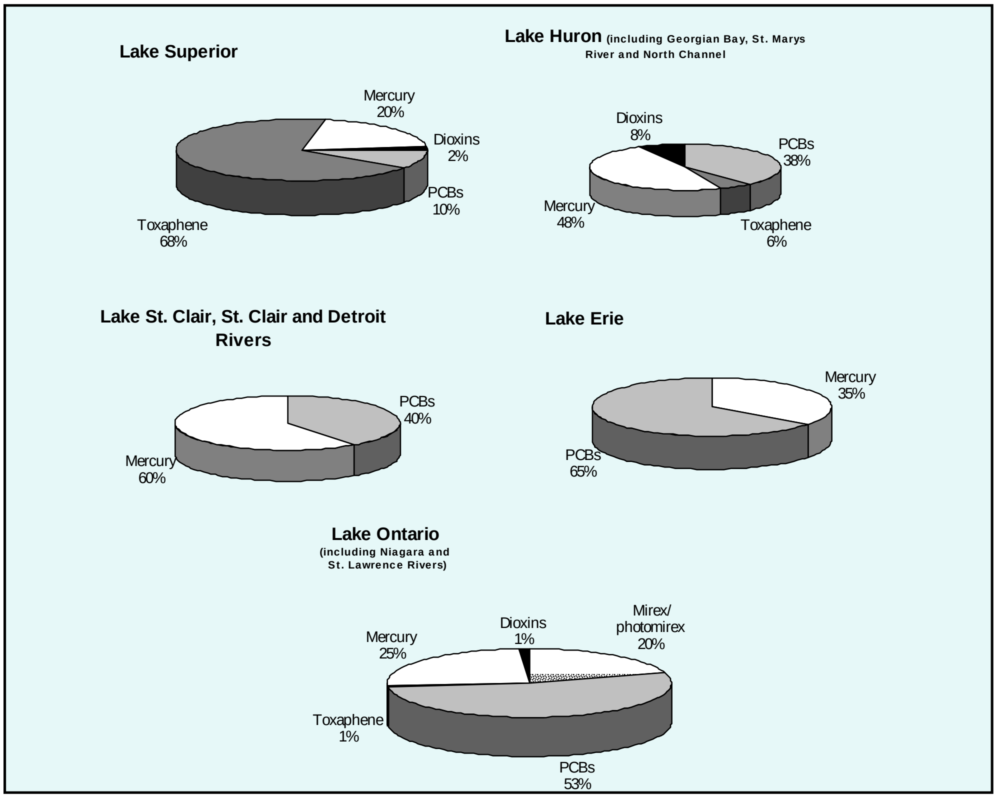


Figure 23. Consumption Limiting Contaminants in Each of the Four Canadian Great Lakes. Percentages indicate the proportion of consumption advisories issued due to that contaminant.
Source: Ontario Ministry of Environment, 1999.

Contaminant Trends

After a decade or more of decline, the concentration of some contaminants appears not to be decreasing at the same rate as in previous years, whereas other contaminant concentrations are fluctuating about a level reached in the 1980's. **Mercury** is an example of such a contaminant. Figure 24 shows that mercury concentrations in walleye have not changed significantly in Lake St. Clair over the past decade, and this trend is true for mercury in many fish species throughout the Great Lakes. There has, however, been a dramatic change in the food chain which is occurring at many locations in the Great Lakes, due in large part to zebra mussel infestation. These changes confound conclusions regarding overall Great Lakes trends. Mercury levels in forage fish species such as smelt tend to be higher in the upper Great Lakes (Figure 25), while there is little difference in mercury levels for lake trout between Lakes.

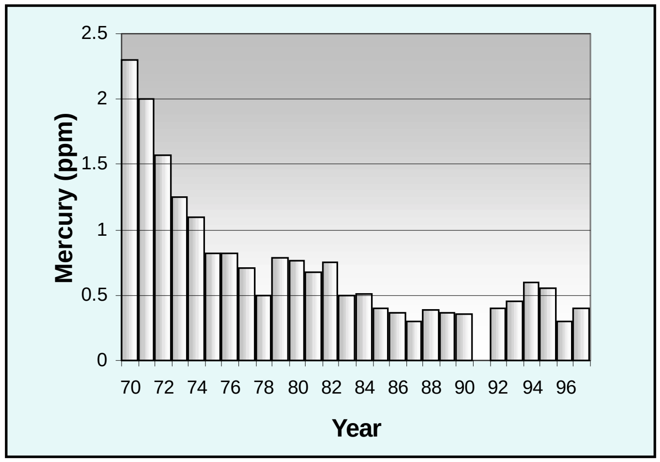


Figure 24. Mercury Concentrations in 45 cm Walleye, Lake St. Clair.
Source: Ontario Ministry of Environment, 1999.

Concentrations of DDT in fish appear to have remained relatively stable for the last several years. Since a pattern of increasing concentrations appeared in the mid to late 1980's, DDT levels have fluctuated around a point representing the lowest concentration measured in fish over the past 20 years. Statistical analysis, however, shows that there is a continuing decline in DDT levels consistent with the decline seen since the early 1970s. DDT levels are still highest in Lake Ontario fish and lowest in those of Lake Superior (Figure 26). There are currently no fish consumption advisories for DDT in Great Lakes fish.

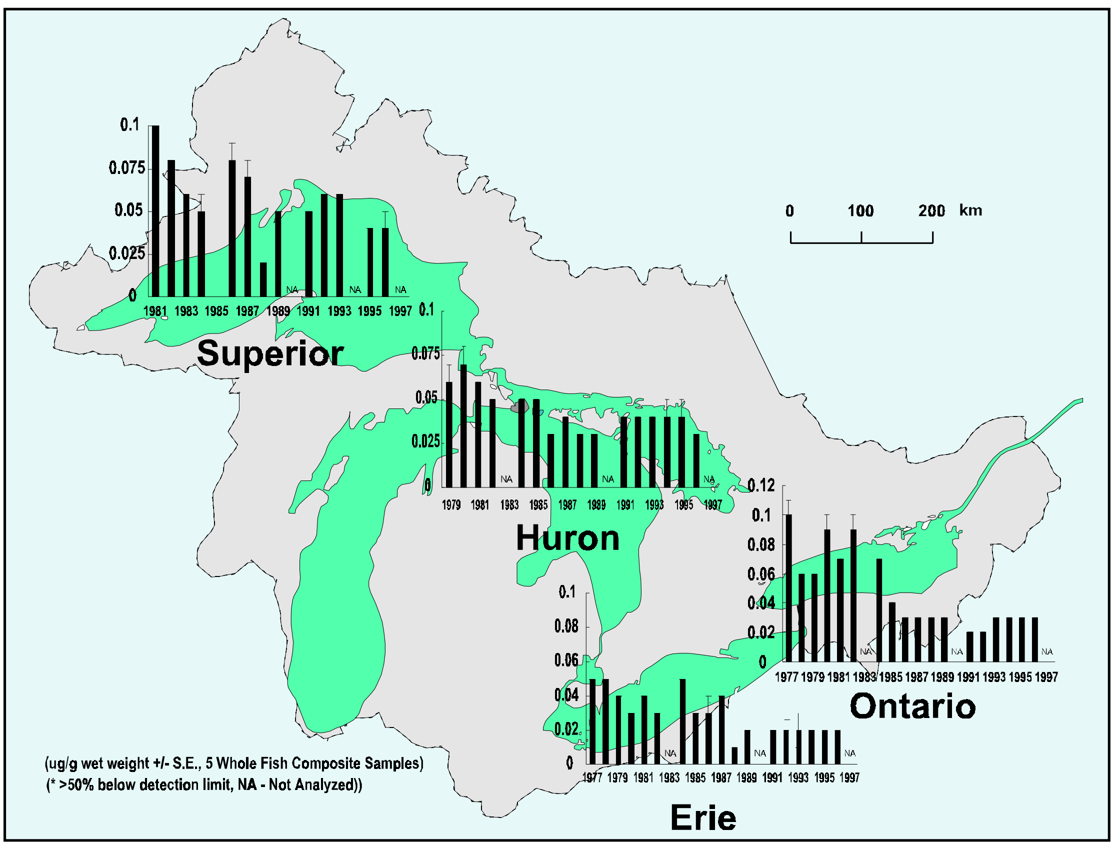
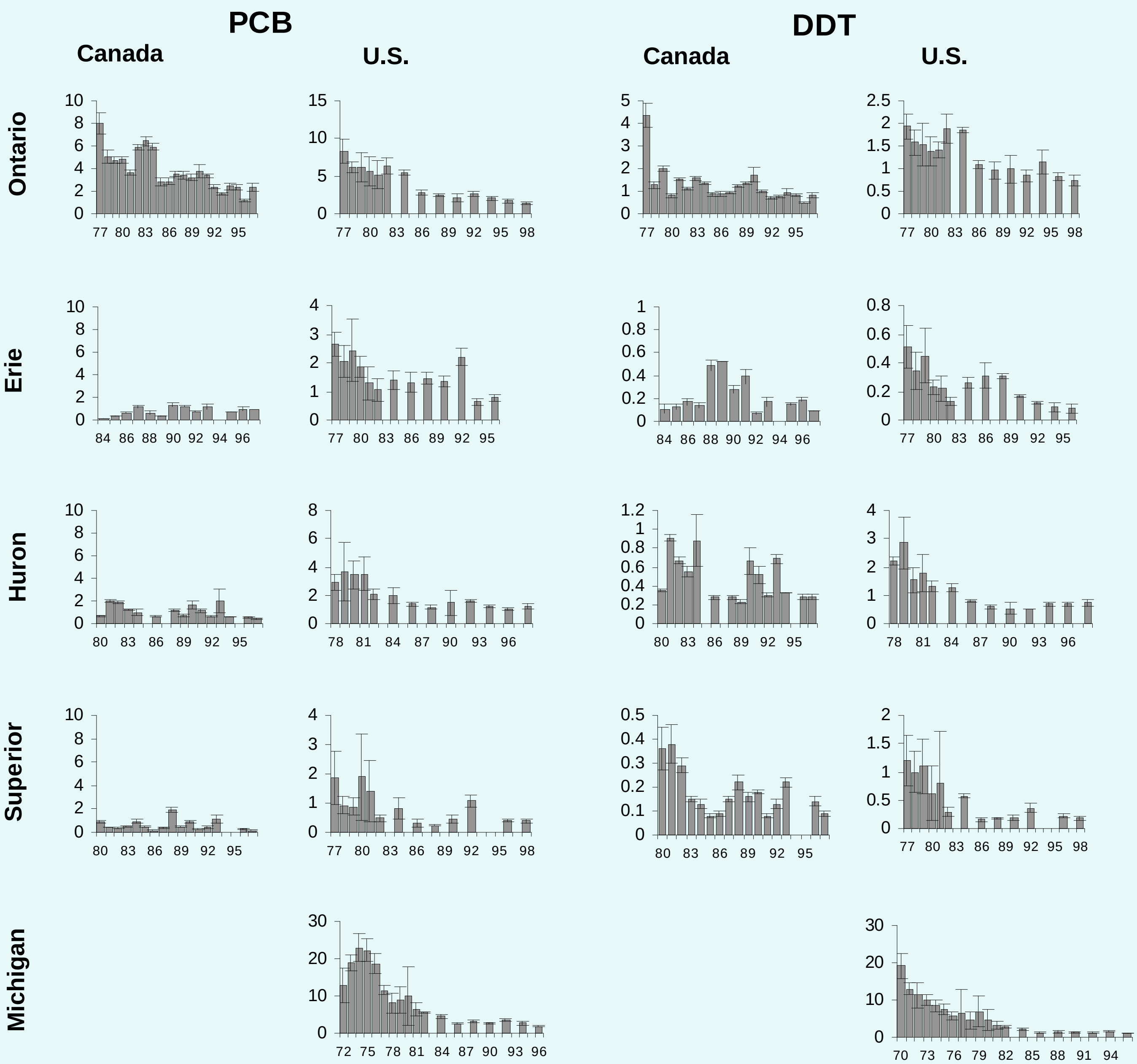


Figure 25. Total Mercury Concentrations in Whole Rainbow Smelt (1977-1997).
Source: Department of Fisheries and Oceans Canada, 1998.



Note:
1. Canadian PCB and DDT data: ug/g wet weight +/- S.E., whole fish, age 4+ yrs., NA - not analyzed
2. U.S. PCB and DDT data: ug/g wet weight +/- 95% C.I., whole fish, composite samples, 600-700 mm size range (Lake Erie data are for walleye in the 400-500 mm size range)

Figure 26. PCB and DDT found in Whole Lake Trout (1977-1997). (Note the different scales between lakes).
Source: Department of Fisheries and Oceans Canada, 1998, and U.S. Environmental Protection Agency, 1998.

Similar to DDT, concentrations of total PCB have demonstrated a decline over the last two decades at most monitoring locations. Although total PCB concentrations in top predator fish (lake trout, salmon and walleye) remain at levels approximately one-tenth that of their peak in the mid-1970's, concentrations are still high enough that fish consumption advisories remain in place for all five Great Lakes. Fluctuations in PCB concentrations that have been observed in Lake Erie and Lake Michigan fish may be caused by changes in the composition of the food web (Figure 26).

Chemical Contaminant Intake from Air, Water, Soil and Food

Pressure Indicator (4088)

As most North Americans, Great Lakes basin residents are exposed to persistent contaminants through the ingestion of food and water, the incidental ingestion of soil and house dust, and the inhalation of air (indoors and out). This indicator tracks contaminant levels in various media and their intake via ingestion and inhalation, and indirectly estimates the potential harm to human health and the efficacy of policies and technology intended to reduce PBT chemicals.

Exposure assessments for the Canadian Great Lakes basin population have been completed for 11 PBT chemicals (aldrin/dieldrin, benzo(a)pyrene, chlordane, DDT, dioxins and furans, hexachlorobenzene, mercury, mirex, octachlostyrene, PCBs, and toxaphene). Daily intakes have been estimated for the following age groups : 0 - 0.5 years, 0.5 - 4 years, 5 - 11 years, 12 - 19 years, 20 + years, and total lifetime, using available data up to 1996. The assessments provide a snap-shot of current human exposure to persistent chemicals in the environment, and are useful for gauging trends in population exposures over time. Estimated daily intakes can be updated periodically, as new data become available.

For many of the Great Lakes PBT chemicals, the highest estimated daily intakes appear in the youngest age groups and especially for infants who are exclusively breast-fed, albeit for a relatively brief portion of overall lifetime exposure (Figure 27).

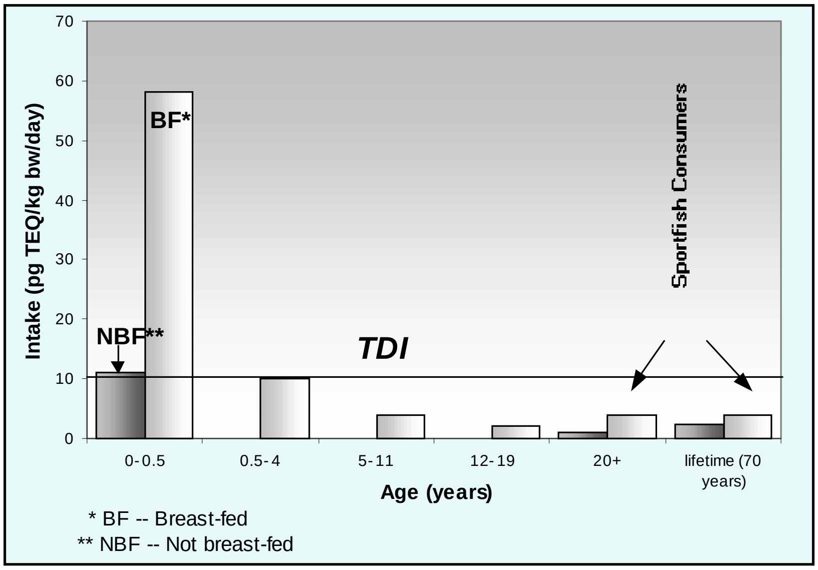


Figure 27. Estimated Intake of Dioxins and Furans [Estimated Daily Intake expressed in picograms toxic equivalents per kg body weight per day (pg TEQ/kg bw/day)].
Source: Health Canada, 1998.

Air Quality

Pressure Indicator (4176)

Air pollution does not respect geographical or political boundaries. Cities around the Great Lakes basin continue to experience many days a year where the quality of air is unacceptable according to federal, state or provincial guidelines. The inhalation of polluted air can pose significant health threats to humans, especially to specific populations at risk such as the young, the elderly and those with recurring respiratory problems. This indicator will monitor the air quality in the Great Lakes ecosystem and tie into the potential impact of air quality on human health in the Great Lakes basin.

Studies conducted in the Great Lakes region and elsewhere have provided strong evidence linking priority air pollutants, such as ground-level ozone (described below), airborne particles, and acid aerosols, to reduced lung function in children, to increased rates of hospital admission for respiratory and cardiac diseases, and to increased death rates.

Ground-level Ozone

This gas is created in the presence of high temperatures and sunlight, when oxides of nitrogen and hydrocarbons interact in the atmosphere. Recent studies have found a significant association between atmospheric ozone and sulphate levels and the number of daily hospital admissions for respiratory conditions (Figure 28). These findings show that exposure to even low levels of outdoor air pollutants can cause adverse effects on cardiorespiratory health. In particular, there does not appear to be a level for ozone below which no adverse respiratory health effects are observed. Ozone pollution is most common during the summer months and is closely monitored in most major cities in Ontario and the U.S. (Figure 29).

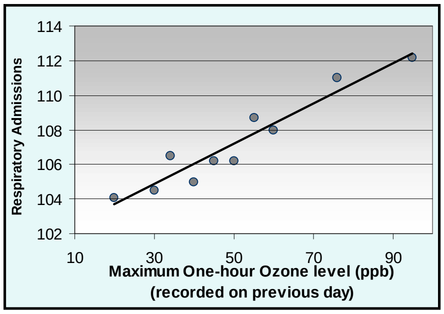


Figure 28. Relationship between Daily Respiratory Admissions and Daily Maximum 1-hour Ozone Levels (ppb) on the Previous Day, Ontario Hospitals, 1983-1988.
Source: Burnette et al, 1994.

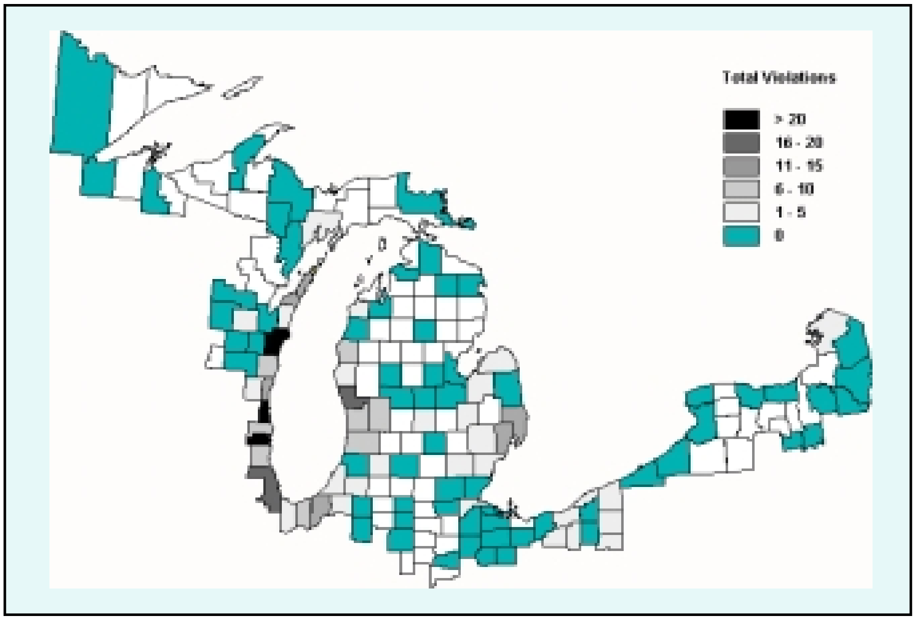


Figure 29. U.S. Great Lakes Counties with Violations of Ozone Air Quality Standard, 1990-97.
Source: U.S. Environmental Protection Agency.

Chemical Contaminants in Human Tissue

Pressure Indicator (4177)

With increasing public education and concern, residents of the Great Lakes basin are becoming more aware of the presence of persistent, bioaccumulating, toxic substances in the air, water and some food sources. As a result, more emphasis is being placed on the effects of PBT chemicals on short-term and long-term human health. Although progress has been made in reducing or eliminating the production and release of these substances in the Great Lakes, many of them are so persistent that through bioaccumulation and biomagnification within the food chain, contaminants remain within the ecosystem, as does the potential risk to humans. Primarily because of their persistence and presence in the food chain, these substances are also taken in by humans and tend to accumulate in their tissues. Substances of concern include PCBs, DDT, DDE, heavy metals such as mercury, and many others.

In the future this indicator will report on the concentrations of PBT chemicals (targeted by the GLWQA) in human tissues including blood, breast milk, hair and adipose (fat) tissues. Implications on the efficacy of policies and technology to reduce PBT chemicals in the Great Lakes ecosystem can also be assessed through data presented with this indicator.

Trends in Chemical Contaminants in Human Tissue

Over the past 20 years, there have been steady declines in the concentrations of many key pollutants in the environment, leading to declines in levels in human tissues, for example, lead in blood, and organochlorine contaminants in breast milk. Composite levels of seven persistent organochlorine pesticides in human breast milk in Canada have declined 80% since 1975 (Figure 30). This translates into a reduced risk to health. The banning and restrictions on the use of Great Lakes critical pollutants has been the greatest reason for decreases in the body burden of these PBT chemicals in Great Lakes basin residents. Improved promotion strategies for fish consumption advisories and more advanced and extensive public education in recent decades, have also contributed to reducing the body burdens.

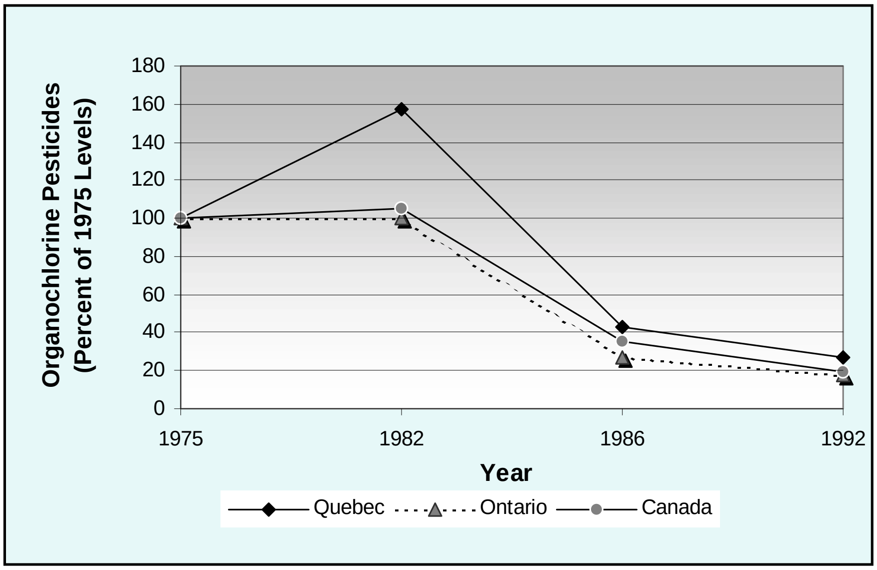


Figure 30. Aggregate Mean Concentrations of Seven Organochlorine Pesticides in Human Breast Milk - Ontario, Quebec, and Canada, 1975-1992 (expressed as percentages of 1975 levels).
Source: Craan and Haines, 1998.

3.1.6 Societal

Integrated management of society as part of the ecosystem requires organization of human activities consistent with the need to respect other ecosystem components. For example, the creation and discharge of waste materials by humans may have an impact on the habitat of plant and animal species, result in contamination and other health problems. From an aesthetic viewpoint, trash, oil slicks, sludge, smog etc., are easily noticed and offensive to a well developed and organized society.

Socio-economics, stewardship and other societal aspects of Great Lakes communities are not easy to monitor due to the complexity of the relationships between jurisdictions and the lack of a coordinated approach towards developing and monitoring indicators. For this reason, the societal indicators developed for SOLEC 98 are still in a very preliminary stage and under continuing review. A more comprehensive set of societal indicator will be presented at SOLEC 2000.

Socio-Economics

The health of the environment is closely tied to a region's economy as well as its societal values. In the Great Lakes region, an international border separates distinct political traditions and national cultures, but despite this, an integrated economy has developed - with a strong resource base and manufacturing complex. However, increased competition from both domestic and global economies, a maturing industrial infrastructure, continued urbanization and the environmental impacts of economic and social activity are forcing a new development path - one that both supports the economy and preserves the environment.

Stewardship and Sustainability

A "steward" is someone who manages the affairs of a household or estate on behalf of an employer, owner, or beneficiary. "Stewardship" is a process requiring competence, vigilance, and an ethic of responsibility for the condition of that which is being looked after.

Stewardship is not sustainability, but sustainability provides the conceptual structure for which the process of stewardship is pursued. That is, stewardship activities are intended to achieve a sustainable future — *a balance between environmental integrity, economic viability, and social well being.* In this regard, stewardship is closely related to ecosystem-based management which seeks to sustain ecosystem integrity across time.

Within this suite of proposed Great Lakes indicators, sustainability is implicit within the entire set, and a separate set of indicators for sustainability would be redundant. A comprehensive set of indicators to assess human activities, or "program responses," however, reflects our collective stewardship of the Great Lakes ecosystem - our individual and collective actions to halt, mitigate, adapt to, or prevent damage to the environment.

Citizen/Community Place-Based Stewardship Activities

Human Activity Indicator (3513)

Like many of the other societal indicators, this one will be a challenge to monitor. The proposed measure is an enumeration and description of programs and projects that engage citizens in the stewardship of their ecosystems and/or foster the ethic of stewardship. It might include the total number of identified programs, the total number of program participants and the location of the projects throughout the Great Lakes basin.

While the task of enumerating the hundreds of community projects across the Great Lakes basin is enormous, at this time it is possible to provide examples of some of the high quality, effectively implemented projects being carried out across the basin that have a goal of protecting some aspect of the Great Lakes ecosystem. The importance of community projects that have demonstrated a strong commitment to the environment was recognized at SOLEC 96 and 98. Projects were nominated against a set of “success story” criteria:

- Showed improvement in the Great Lakes ecosystem;
- Forged linkages among economy, environment, and community;
- Created a “win-win” solution;
- Formed strong partnerships;
- Established sustainability as a goal;
- Fostered broad stakeholder involvement; and
- Demonstrated adequate monitoring of effectiveness.

In 1996, seven projects ranging from responsible industrial land-owners to active local citizens groups, were chosen as Success Story recipients. The following five projects were selected for recognition in 1998:

Brantford Division of Union Gas Limited

When it came time for a new customer service building in Brantford, Ontario, the management at Union Gas felt it was important to implement a philosophy of sustainable development into the building design and the surrounding landscape. Lands around the property, known as the Brant Prairie, were restored to their natural state, including Tall Grass Prairie, an oak-maple forest and sedge marsh. Rare indigenous plant species were identified during the naturalization process, including the Fringed Gentian and the Partridge Pea. The latter had been recorded in Ontario but not seen for 80 years.

Because it is a naturalized landscape, the Brantford customer service centre requires no mowing, watering, spraying or fertilizing. The local marsh provides habitat for various species of plans, birds, butterflies, frogs and wildlife. School groups and other visitors can explore trails on the site, and learn about natural heritage, biodiversity and sensitive ecosystems through the outdoor classroom.

The City of Buffalo

Industrial decline and restructuring have been particularly pronounced in Great Lakes cities like Buffalo where industrial activities have concentrated on the waterfront. Buffalo faces enormous economic, social and environmental challenges and many of these challenges are tied directly to brownfields. More than 10,000 acres have been vacated and/or are under-utilized. The City of Buffalo has had notable success in removing threats to human health and the environment and returning contaminated lands to productive use.

Successful brownfield redevelopment projects have resulted in the excavation and clean up of over 17,000 cubic yards of petroleum soaked soil. One site now houses 18 acres of high-tech hydroponic tomato greenhouses and exemplifies the efforts underway to help the community make a transition from a heavy-industry based economy to a more diverse and sustainable economic base.

The City of Buffalo does not and cannot separate its brownfields strategy from its overall long range development strategy for sustainability. Several long-term plans are currently being developed and implemented to promote job creation, provide long-term environmental protection, improve ecological conditions and provide the region with a strong economic base.

Buffalo River Habitat Restoration Sites

The Buffalo Fish and Wildlife Habitat Restoration Demonstration Project has transformed over 10 acres of former brownfield property into a string of three pocket parks along the Buffalo River. This is a collaborative effort involving Erie County, U.S. EPA, the City of Buffalo and New York State agencies, local community organizations and industry.

These sites are designed to benefit urban neighbourhoods as well as wildlife. The Buffalo River awaits boaters, canoeists, fishermen, naturalists, picnickers and folks who just want to get away from it all.

Rondeau Bay Rehabilitation Program

In response to the ban on lead, this Chatham based environmental group mounted its first “take a little lead out” project during the summer of 1997 to encourage fishers to exchange their lead jigs and sinkers for non-toxic alternatives.

The Watershed Rehabilitation Program teamed up with local bait shops and sporting good stores to offer the alternative materials free of charge. In addition, two students hired to survey fishers’ catches took time to point out the benefits of using alternative metals. Local radio stations helped out with public service announcements and reduced-rate advertising, while a number of fishing and wildlife organizations spread the word to their members.

The Rondeau Bay group collected just over 100 kilograms of lead sinkers, jigs, and slip shot during 1997. With a supply of alternative materials left over, the group continued the exchange program through 1998.

The Waukegan Harbour Citizens Advisory Group

The Waukegan Harbor Citizens Advisory Group was recognized for its progress in the Waukegan Harbor Area of Concern. This Success Story recipient exemplifies the broad stakeholder involvement. Monitoring efforts have documented reduced contaminant levels in harbour fish, which allowed the removal of fish consumption advisory signs at Waukegan Harbor in February, 1997. Sign removal was a major milestone showing environmental improvement following remediation of harbour sediments in 1993.

Strong public participation and cooperation of many stakeholders has continued since the advisory group was formed in 1990. A brownfield pilot was initiated through efforts of the advisory group and the City of Waukegan has recently applied for a U.S. EPA brownfield grant to further this effort. Additional dredging of the harbour for navigational purposes is being pursued with the U.S. Army Corps of Engineers.

Remedial Action Plan Updates

One cannot have a discussion on citizen/community place-based stewardship activities without briefly touching on Remedial Action Plans or RAPs of which Waukegan Harbour is one. There are 42 Areas of Concern (AOCs) around the Great Lakes, having impairments to one or more “beneficial uses.” One AOC, Collingwood Harbour, has been delisted. Many of these AOCs have received decades of abuse. Identifying the problems, and planning and implementing the remedial strategies necessary to restore the beneficial uses in these areas can also take many years. For each AOC a Remedial Action Plan has been (or is in the process of being) developed. Restoration of beneficial uses within the AOCs is the primary mission of RAPs and is an essential step in restoring the integrity of the Great Lakes basin ecosystem. Local involvement is integral to the success of the remediation effort, and communities throughout the basin are working together in the clean-up process (through RAPs) to restore and protect environmental quality in these areas. Table 3 shows the status of the beneficial use impairments for each AOC.

Table 3. Great Lakes Areas of Concern: Impairment of Beneficial Uses (as of June 1999 unless otherwise noted)

Area of Concern		IJC CRITERIA (1987) IMPAIRED USES														
		Restriction on fish and wildlife consumption	Tainting of fish and wildlife flavor	Degradation of fish and wildlife populations	Fish tumors or other deformities	Bird or animal deformities, reproduction problems	Degradation of benthos	Restrictions on dredging activities	Eutrophi-cation with undesirable algae	Restriction on drinking water; taste and odor problems	Beach closures	Degradation of aesthetics	Added costs to agriculture & industry	Degradation of plankton (phyto & zoo) communities	Loss of fish and wildlife habitat	Number of local impaired beneficial uses
	Peninsula Harbour *															5
	Jackfish Bay *															6
Lake	Nipigon Bay *				AA											5
Superior	Thunder Bay *															10
	St. Louis Bay/River	fish only							SP							8
	Torch Lake															3
	Deer Lake															1
	Manistique River															6
	Lower Menominee R.															6
	LowerGreenBay & FoxR.															11
Lake	Sheboygan River															9
Michigan	Milwaukee Estuary															11
	Waukegan Harbor															5
	Grand Calumet R.															14
	Kalamazoo River															8
	Muskegon Lake															6
	White Lake *															8
	Saginaw River/Bay															12
Lake	Collingwood Harbour	NL														0
Huron	Severn Sound *															8
	Spanish Harbour *	NL				AA								AA		2
	Clinton River															8
Lake Erie	Rouge River															9
	River Raisin			fish only												9

Area of Concern		IJC CRITERIA (1987) IMPAIRED USES														
		Restriction on fish and wildlife consumption	Tainting of fish and wildlife flavor	Degradation of fish and wildlife populations	Fish tumors or other deformities	Bird or animal deformities, reproduction problems	Degradation of benthos	Restrictions on dredging activities	Eutrophi-cation with undesirable algae	Restriction on drinking water; taste and odor problems	Beach closures	Degradation of aesthetics	Added costs to agriculture & industry	Degradation of plankton (phyto & zoo) communities	Loss of fish and wildlife habitat	Number of local impaired beneficial uses
Lake Erie (con`d)	Maumee River	Impaired	Requires Further Assessment	Impaired	Impaired	Not Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Requires Further Assessment	Requires Further Assessment	Not Impaired	9
	Black River	Impaired	Requires Further Assessment	Impaired	Impaired	Requires Further Assessment	Impaired	Impaired	Requires Further Assessment	Requires Further Assessment	Impaired	Impaired	Requires Further Assessment	Requires Further Assessment	Impaired	8
	Cuyahoga River	Impaired	Requires Further Assessment	Impaired	Impaired	Requires Further Assessment	Impaired	Impaired	Impaired	Requires Further Assessment	Impaired	Impaired	Not Impaired	Requires Further Assessment	Impaired	9
	Ashtabula River	Impaired	Not Impaired	Impaired	Impaired	Requires Further Assessment	Impaired	Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Requires Further Assessment	Impaired	6
	Presque Isle Bay	Not Impaired	Not Impaired	Not Impaired	Impaired	Not Impaired	Not Impaired	Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	2
	Wheatley Harbour *	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Impaired	Requires Further Assessment	Not Impaired	Requires Further Assessment	Not Impaired	Not Impaired	Not Impaired	Impaired	2
	Buffalo River	Impaired	Requires Further Assessment	Requires Further Assessment	Impaired	Requires Further Assessment	Impaired	Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Impaired	5
Lake Ontario	Eighteenmile Creek	Impaired	Not Impaired	Requires Further Assessment	Requires Further Assessment	Requires Further Assessment	Impaired	Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Requires Further Assessment	Not Impaired	3
	Rochester Embayment	Impaired	Requires Further Assessment	Impaired	Requires Further Assessment	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	12
	Oswego River	Impaired	Not Impaired	Impaired	Requires Further Assessment	Requires Further Assessment	Requires Further Assessment	Not Impaired	Impaired	Not Impaired	Not Impaired	Requires Further Assessment	Not Impaired	Requires Further Assessment	Impaired	4
	Bay of Quinte	Impaired	Not Impaired	Impaired	Requires Further Assessment	Not Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Not Impaired	Impaired	Impaired	10
	Port Hope *	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	1
	Metro Toronto *	Impaired	Not Impaired	Impaired	Requires Further Assessment	Requires Further Assessment	Impaired	Impaired	Impaired	Not Impaired	Impaired	Impaired	Not Impaired	Requires Further Assessment	Impaired	8
	Hamilton Harbour *	Impaired	Not Impaired	Impaired	Impaired	Requires Further Assessment	Impaired	Impaired	Impaired	Not Impaired	PROG	Impaired	Not Impaired	Requires Further Assessment	Impaired	9
Connecting Channels	St. Marys River	Impaired	Not Impaired	Impaired	Impaired	Not Impaired	Impaired	Impaired	Impaired	Not Impaired	Impaired	Impaired	Not Impaired	Not Impaired	Impaired	9
	St. Clair River	Impaired	Requires Further Assessment	Requires Further Assessment	Requires Further Assessment	Impaired	Impaired	Impaired	Not Impaired	Impaired	Impaired	Impaired	Impaired	Not Impaired	Impaired	9
	Detroit River	Impaired	Impaired	wildlife only (Requires Further Assessment)	Impaired	Requires Further Assessment	Impaired	Impaired	Not Impaired	Impaired	Impaired	Impaired	Not Impaired	Not Impaired	Impaired	9
	Niagara River (ON) *	Impaired	Not Impaired	Impaired	Not Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Impaired	Not Impaired	Not Impaired	Requires Further Assessment	Impaired	9
	Niagara River (NY)	Impaired	Not Impaired	Requires Further Assessment	Impaired	Requires Further Assessment	Impaired	Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Not Impaired	Impaired	5
	St. Lawrence R. (ON)	Impaired	Not Impaired	Impaired	Requires Further Assessment	Requires Further Assessment	Impaired	Impaired	Impaired	Restored	Impaired	Restored	Not Impaired	Requires Further Assessment	Impaired	7
	St. Lawrence R. (NY)	Impaired	Not Impaired	Requires Further Assessment	Requires Further Assessment	Requires Further Assessment	Requires Further Assessment	Not Impaired	Not Impaired	Requires Further Assessment	Not Impaired	Not Impaired	Not Impaired	Requires Further Assessment	Impaired	2

Impaired
Requires Further Assessment
Restored
Not Impaired

NL - Impaired but not attributable to local sources
AA - After additional assessment not impaired
SP - Excess loadings of sediment and nutrients to the lake
PROG - Progress has been made, 2 beaches have opened, but further restoration is necessary
* The status of the beneficial use impairments still to be confirmed

3.1.7 Unbounded

Acid Rain

Pressure Indicator (9000)

Acid rain is caused when two common air pollutants (sulphur dioxide — SO_2 and nitrogen oxide — NO_x) are released to the atmosphere, mix with high altitude water droplets and return to the earth as acidic rain, snow, fog or dust. These pollutants can be carried over long distances by prevailing winds, creating acid precipitation far from the original source of the problem. Environmental damage often occurs when natural geological processes on the earth's surface are unable to neutralize the acid being deposited.

Many compartments of the environment can be affected by acid rain. Lakes and rivers are known to become acidified due to highly acidic precipitation. This can cause the disappearance of many species of fish, invertebrates and plants. Not all lakes exposed to acid rain become acidified. Lakes formed on a limestone foundation rich in calcium carbonate are able to neutralize acid deposition. Much of the acid precipitation in North America falls in areas around and including the Great Lakes basin. Northern Lakes Huron, Superior and Michigan and their tributaries and small inland lakes are located on the geological feature known as the Canadian Precambrian Shield where rock is mostly granite. These lakes cannot neutralize acid, leading to the "death" of many of these small lakes (many of which are in northern Ontario). The five Great Lakes themselves are so large that acid precipitation has little effect on them directly. Impacts are mainly felt on vegetation and on inland lakes.

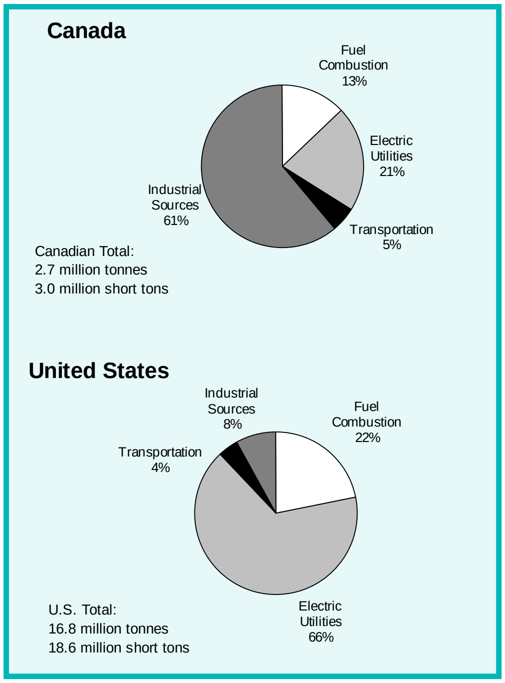


Figure 31. Sources of Sulphur Dioxide Emissions in Canada and the U.S. (1995).
Source: Governments of Canada and the U.S., 1998.

Humans can also be affected by acid in the atmosphere. Sulphate particles that form one of the primary components of acid rain also react in the atmosphere to create urban smog which is a key human health hazard (Air Quality indicator).

Sulphur dioxide emissions come from a variety of sources. Most common releases of SO_2 in Canada are a byproduct of industrial processes. In the United States, emissions from electrical utilities constitute the highest releases (Figure 31). The primary source of NO_x emissions in both countries is the combustion of fuels in motor vehicles.

The effects of acid rain can be seen far from the source and so the governments of Canada and the United States are working together to reduce acid emissions. The 1991 Canada/United States Air Quality agreement addresses transboundary air pollution. To date, work on this agreement has focussed on acid rain and significant steps have been made in the reduction of SO_2 and NO_x emissions.

The two measures proposed for this indicator are, 1) Levels of pH in precipitation in the Great Lakes basin, and 2) the area within the Great Lakes basin in exceedance of critical loadings of sulphate to aquatic systems, measured as wet sulphate residual deposition over critical load (kg/ha/yr). From data collected to support this indicator, potential stress to the Great Lakes ecosystem due to acid rain, and the efficacy of policies to reduce sulphur and nitrogen acidic compounds can be evaluated.

Figure 32 illustrates the trends in SO_2 emission levels in Canada and the United States from 1980 and predicted to 2010. U.S. levels will have decreased by approximately one-third by 2000 and 40% by 2010 and Canadian levels dropped 54% from 1980 to 1994. Emissions for the next ten years are predicted to remain at approximately current levels. Unfortunately, despite these efforts rain is still acidic throughout most of the region.

Figure 33 compares wet sulphate deposition over eastern North America between two five-year periods, 1980-84 and 1991-95 in kilograms per hectare per year. Deposition has decreased during the period corresponding to the decrease in SO_2 emissions. If SO_2 emissions level out at current values as predicted, it is unlikely that sulphate deposition will change in the coming decade. The predicted sulphate deposition exceedences of critical loads for 2010 in Canada is seen in Figure 34.

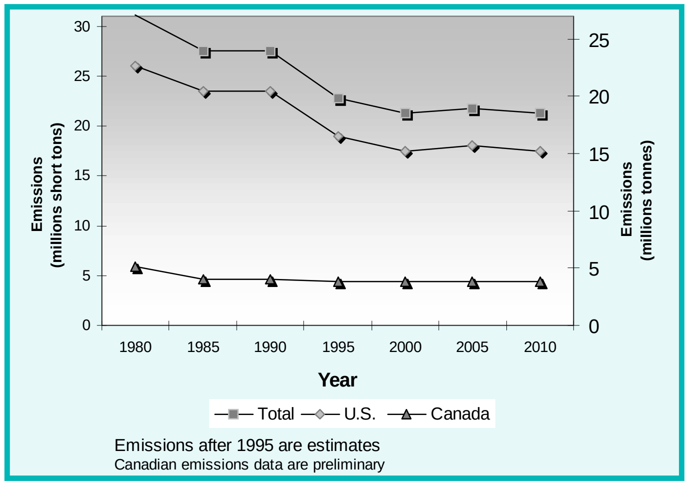


Figure 32. Past and Predicted Sulphur Dioxide Emissions in Canada, the U.S. and Combined.
Source: Governments of Canada and the U.S., 1998.

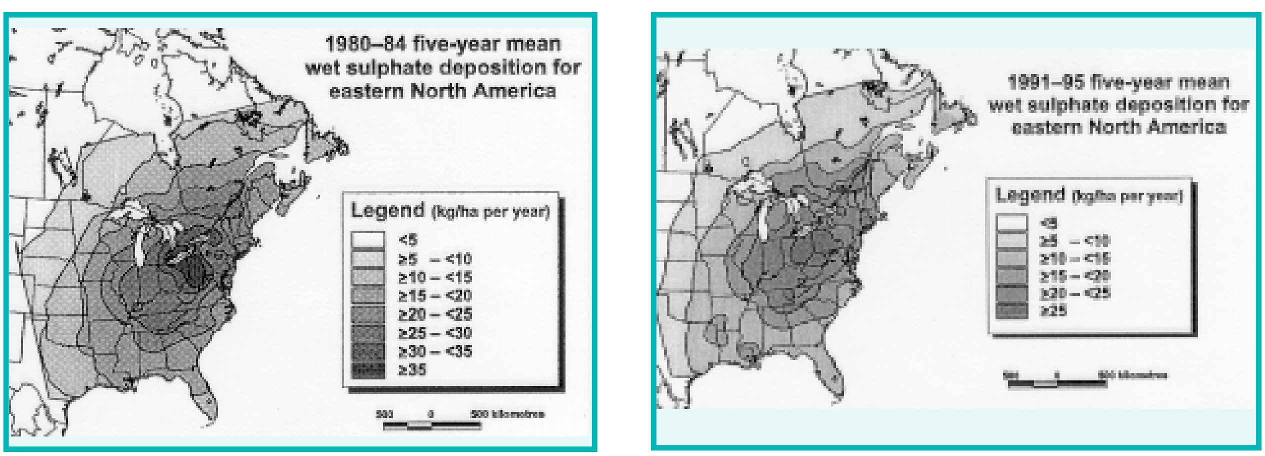


Figure 33. Comparison of Wet Sulphate Deposition in Eastern North America from 1980-84 (average) and 1995.
Source: Governments of Canada and the U.S., 1998.

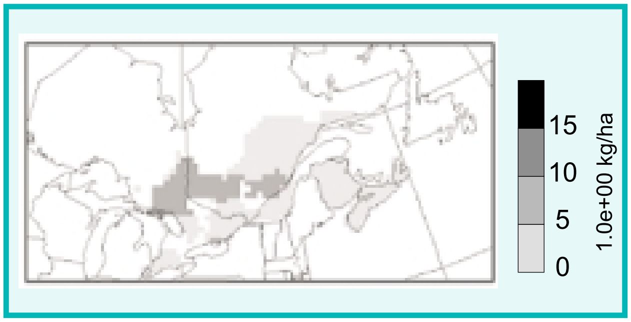


Figure 34. Predicted 2010 Sulphate Deposition Exceedances of Critical Loads.
Source: Governments of Canada and the U.S., 1998.

Sudbury, Ontario

Some of the greatest improvements in environmental health as a result of decreased sulphate emissions has been seen in Sudbury, Ontario. This region is known for heavy industry and historically high SO_2 emissions. The seven thousand lakes found in the heavily forested region are underlain by granite bedrock making acidification a serious problem. Some of the most well documented fishery losses in Canada resulting from acid rain are in the Sudbury area. Since 1980 widespread improvements have been recorded in the biological and chemical health of the lakes in the Sudbury area. Fish populations have rebounded as have fish-eating birds such as loons. The rebound of the aquatic ecosystems in the area are largely due to dramatic reductions in local smelter emissions (Figure 37). SO_2 emissions from the two largest producers of smelter emissions, Inco and Falconbridge, have been reduced by 75% and 56% respectively.

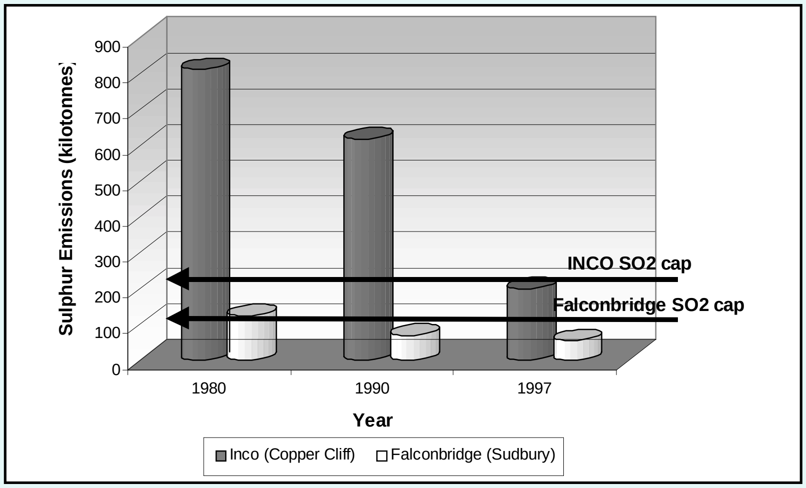


Figure 35. Major Industrial Sources of Sulphur Dioxide in the Sudbury Region, Ontario, Canada.
Source: Environment Canada, 1999

3.2 Lake Updates

Information presented in the indicators will help us determine the state of major ecosystem components of the Lakes. As has already been mentioned, the information is incomplete at this time, the gaps are too big to make a thorough assessment of the health of the Great Lakes basin ecosystem. To help give a more complete picture of the state of the Lakes, the following sections present additional information on some of the recent changes within each lake.

It should be noted that there are changes in stresses happening in the lakes that are translating into shifts in the aquatic community (especially prey species). This will sometimes create an opportunity for a return to native species and possibly even the communities-of-old and other times will cause the replacement of native species with non-native species.

The nearshore zone of the Lakes will become even more important in the future as an area that release nutrients, providing nutrients to the entire lake ecosystem. Newly built marinas, rip-rap shorelines, and other land use changes are having impacts on the nearshore environment. With these rapidly increasing human-induced pressures, it is important that lake managers recognize the importance of this area and continue working towards protecting and improving nearshore habitat.

For sources of information on each of the lake updates, please see page 89.

3.2.1 Lake Superior

Exotic Species

- No significant Eurasian ruffe range expansion has been observed since 1995. U.S. Fish and Wildlife Service reports that infestation has moved slightly eastward to the Firesteel River (approximately 50 miles west of Houghton). This invasive fish was first discovered in 1986 in the Duluth-Superior Harbor when 66 specimens were collected. By 1991, the infestation had grown to an estimated 2 million and by 1996 grew to an estimated 6 million fish (based on bottom trawl samples). In Lake Superior, ruffe are also found along the North Shore to Two Harbors, at Taconite Harbor and in Thunder Bay, Ontario. No inland lakes within the Great Lakes basin are infested. While impacts of ruffe on fisheries have been difficult to quantify, recent research indicates that yellow perch growth is significantly reduced in the presence of ruffe and there is more diet overlap than earlier reported. Ruffe may also impact lake herring and other fall spawning fishes causing a new source of overwintering mortality.

- Zebra mussels are found at nine locations on Lake Superior with the most significant infestations found in Duluth-Superior Harbor and Chequamagon Bay. First found in 1989, this small invasive clam has remained relatively in low numbers in the Duluth-Superior Harbor until fall 1998 when the infestation grew and expanded. Last fall, densities at some locations ranged from 2,000-6,000 per square metre. With overwintering survival at >75%, adults in the summer of 1999 are reproducing - resulting in higher colonization with greater impacts expected on raw water users and recreation.

- The round goby was first found in the Duluth-Superior Harbor in July 1995. To date, the infestation remains in the lower harbor where populations are growing and expanding rapidly. No other confirmed sighting have been reported in Lake Superior, its tributaries or inland lakes within the Basin. Like the other Great Lakes, it is expected that they will displace native fishes such as mottled sculpin and out compete others for food and habitat. A current density of round gobies are 918 per hectare, while in some areas of the Great Lakes densities are over 100 per square metre. The infestation is expected to continue to grow and expand.

- Spiny waterflea was first found in Lake Superior in 1987 likely discharged from the ballast water of ships travelling from the other Great Lakes. It has since spread to 29 inland lakes in the Great Lakes basin. Spiny waterflea can cause subtle effects on Great Lakes fisheries by competing with small fish for food (plankton). Spiny waterflea populations generally "bloom" in late summer when water temperatures warm, however, in 1999 there have been few reports of them collecting on fishing lines, downrigger cables and commercial fishing equipment. They are usually found in the western arm of Lake Superior, the Apostle Islands, and eastern Lake Superior, including Batchawana Bay.

- Rusty crayfish were found in the Duluth-Superior Harbor in June 1999. This is the first time that they have been found in the western basin of Lake Superior, likely released as live bait by non-resident anglers or from the ballast water of ships. They are a very aggressive species that can displace native crayfish populations. While their impacts will be site specific, they can literally clear cut an area of aquatic vegetation — reduce food and habitat for other species (including fish nursery habitat), allow for increased shoreline erosion and sediment resuspension, and can feed on the eggs of native fishes. The other known infestation of rusty crayfish in Minnesota waters of Lake Superior is in the Pigeon River.

Species Recovery

- Lake sturgeon - The trend is for a slight increase in population, but these numbers are still much below historic levels. There are completed rehabilitation plans and active rehabilitation programs planned for this species.
- Walleye - There are also completed rehabilitation plans for this species. Walleye numbers are stable or increasing in U.S. waters (the stocks are fully or nearly recovered).
- Lake herring are recovering, but have not fully recovered as yet. There has been low natural reproduction over the last seven years, although the lake herring in the system are getting larger and stronger. The biomass numbers have been increasing even though the total abundance has decreased slightly.
- Lake trout are now considered a naturally reproducing population and there has been very little stocking since 1997.

3.2.2 Lake Michigan

Exotic Species

- Round gobies have invaded Green Bay. They were first observed in the harbor at Escanaba, MI, several years ago and have recently been sampled in Sturgeon Bay, WI.
- Zebra mussels have recently moved upstream in the Fox River and are now established in Lake Winnebago in Wisconsin.

Species Recovery

Yellow perch in southern Lake Michigan appear to have spawned successfully in 1998. While this is good news in terms of reversing a seven-year trend of poor recruitment, the 1998 year class is relatively small compared to the large year classes of the 1980s that produced the large harvest in the late 1980s to early 1990s. A multi-agency research group is conducting extensive lakewide investigations to determine factors limiting perch recruitment.

Early Mortality Syndrome (EMS), the poor egg survival related to low egg thiamine levels, continues to plague about 25% of female lake trout in Lake Michigan. Research into the cause of the low thiamine levels in lake trout eggs can now be explored.

Successful reproduction of lake sturgeon in three tributaries to Green Bay was documented by the U.S. Fish and Wildlife Service. Eggs or fry were collected from below the first dam on the Fox, Peshtigo, and Menominee Rivers. Sonic tags have been implanted into adult lake sturgeon, to track and determine their distribution and habitat use.

Fish Community Dynamics

Management agencies on Lake Michigan recently reduced stocking numbers for chinook salmon by 20% lakewide to counter the poor survival of the stocked salmon. Survival and sustainability of chinook salmon decreased as a result of the die-off from bacterial kidney disease in the mid to late 1980s. Natural reproduction of chinook salmon in tributaries in state of Michigan streams account for as much as 30-50% of the salmon lakewide.

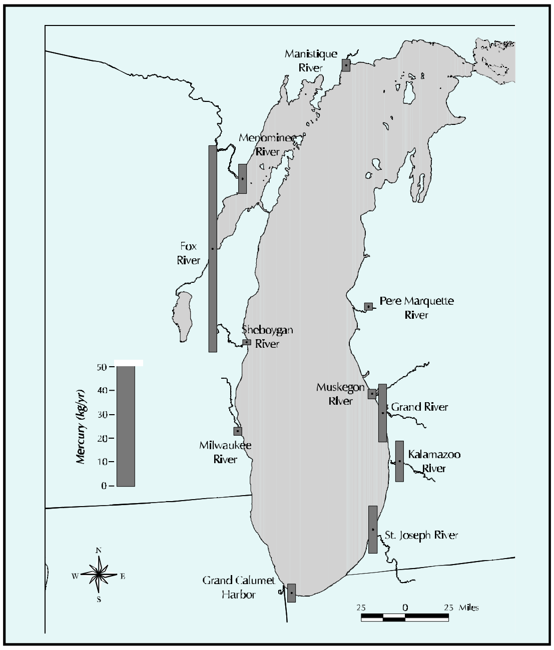
Alewife stocks have not rebounded as dramatically as expected following the reduction in chinook salmon during the 1980s. Several very strong year classes were produced in the 1990s, but have failed to increase adult numbers substantially in subsequent years, due primarily to the continued heavy predation rates from the stocked trout and salmon.

Diporeia Population Decline

Populations of the bottom-dwelling organism, *Diporeia*, have declined dramatically in southern Lake Michigan in recent years. These organisms are usually plentiful in the top of the sediments, and they are an important food for some fish. Research conducted by the Great Lakes Research Laboratory, NOAA, has shown at some locations that the abundance of *Diporeia* declined from 10,000 per square metre in 1980 to less than 100 per square metre in 1993. By 1997, there were completely absent from a site near St. Joseph, Michigan. It is thought that an interaction with zebra mussels is the likely cause of the decline. Large concentrations of zebra mussels in southern Lake Michigan may be filtering out diatoms, and thereby depriving *Diporeia* of food. The impact of lower *Dipoeria* abundance on the survival of juvenile fish in Lake Michigan has yet to be measured, but it will likely lead to significant alterations in the fish community.

Lake Michigan Mass Balance

As part of the enhanced Lake Michigan Mass Balance study, eleven tributaries were monitored for concentrations of total mercury in 1994 and 1995. Based on the measured concentrations and stream flow, the annual average loading of mercury from each tributary to Lake Michigan was calculated (figure 36). Loadings from the Fox River (93 kg/yr) contributed 50% of the total mercury loadings from all the tributaries (186 kg/yr). The estimated loading of mercury from the atmosphere (1048 kg/yr), however, was over 5 times greater than that from all the tributaries combined.



Individual Tributary Loadings (kg/yr)
Fox - 93
Grand - 25
St. Joseph - 20
Kalamazoo - 17
Menominee - 12
Grand Calumet - 7
Manistique - 4
Muskegon - 3
Milwaukee - 2
Pere Marquette - 2
Sheboygan - 1

Figure 36. Individual Tributary Loadings of Mercury to Lake Michigan
Source: U.S. Environmental Protection Agency, 1999.

3.2.3 Lake Huron

Sea Lamprey Control

Lake managers will have control over this exotic species beginning this summer. The lamprey control structures in the St. Marys River will allow for effective control over lamprey entering Lake Huron. Treatment programs finished as recently as July, 1999 in Canada. It is hoped that these measures will encourage population growth of key predator and native species within the Lake that have been held stagnant due to lamprey predation.

Lake Trout Reproducing in Parry Sound

The lake trout fishery in the Parry Sound area of Lake Huron is now considered recovered and self-sustaining and is no longer being stocked. It has only been through the coordinated efforts of the public and government agencies that this was possible. Unfortunately, this is not the case for the rest of the Lake where lake trout are being excessively overharvested in most open lake areas.

The Lake Huron Initiative

During SOLEC 96, conference participants recommended a number of efforts to address environmental issues in the Great Lakes basin. Two key recommendations directly affect Lake Huron:

- The public needs a summary of information on the Lake Huron ecosystem to prioritize actions and effect change; and
- In the absence of a Lake Huron LaMP, initiate a “Lake Huron Alliance” of researchers, implementors, community groups and other interested parties.

In June of 1998 the Lake Huron Conference was held in response to the identification of these needs. A binational gathering of government, industry, and local community initiated a much needed discussion on the issues and efforts required to ensure a sustainable Lake Huron watershed. A Steering Committee for the *Lake Huron Initiative* was identified and the decision to hold a binational Lake Huron Initiative Conference in the winter of 2000 was made. This conference will develop a framework for the Lake Huron Initiative. SOLEC background reports from 1994 and 1996, as well as State of the Great Lakes Reports from 1995 and 1997, have provided the Lake Huron Initiative Steering Committee with valuable information on the status and historic trends of issues and stresses relevant to Lake Huron.

3.2.4 Lake Erie

Beneficial Use Impairment Status

With one-third of the population of the Great Lakes basin residing in the Lake Erie watershed, the Lake is exposed to greater stress due to urbanization and agricultural intensity than any of the other Great Lakes. Despite success in controlling nutrient loadings and the resulting algal blooms, the Lake ecosystem is still subject to many other stresses. The 1999 Lake Erie LaMP Status Report outlines a summary of the status of the evaluated beneficial use impairments of Lake Erie as of June 1998 (Table 4).

Table 4. Lake Erie Beneficial Use Impairments.

Impairment	Causes of Impairment	Impairment Conclusions*
Fish and wildlife consumption restriction	Fish: PCBs, mercury, PAHs. Lead, chlordane & dioxins Wildlife: PCBs, chlordane, DDE, DDT & mirex	Fish: Impaired Wildlife: Inconclusive
Restrictions on dredging activities	PCBs, heavy metals	Impaired
Eutrophication of undesireable algae	Phosphorus levels	Impaired
Recreational water quality impairment	Exceedances of E. coli and/or fecal coliform guidelines	Impaired
Degradation of phytoplankton/zooplankton populations	Zebra and Quagga mussel grazing, species degradation (phytoplankton), high planktivory, species decline, habitat loss/degradation (zooplankton)	Impaired
Degradation of aesthetics	Excessive Cladophora, point/non-point source stormwater runoff, floating garbage & debris, dead fish, excessive zebra mussels on shoreline areas	Impaired

* An assessment of "Impaired" indicates the beneficial use is impaired somewhere in Lake Erie, not necessarily the entire lake (Source: Lake Erie Status Report, 1999).

Eastern Lake Erie

Throughout the 1990s, this area of Lake Erie experienced rapid changes in open water productivity. Open lake waters are considered less productive based on increased water clarity, decreased zooplankton production and overall decreased fishery harvests in over the last decade. Walleye are the most prominent eastern basin predator that has declined in abundance since the 1980s. New exotic species are emerging, and they can significantly alter energy flow in the Lake food web. Prominent among these new invaders are the quagga mussel and round goby. Amid these invasions, there has been an apparent recovery of the nearshore benthic community including increased mayfly abundance. Abundance of some benthic predators, such as smallmouth bass, may expand from these changes.

Western Lake Erie

Exotic species

While the round goby reached its highest abundance in the central basin of Lake Erie, the western basin is still experiencing exponential growth in this exotic species. Ecological impacts stemming from this growth range from the positive impact of gobies utilizing zebra mussels as food and subsequently the gobies themselves providing food for other fish species. On the negative side, there is a concern that the gobies are feeding on zebra mussels which may be heavily contaminated, resulting in certain toxic chemicals entering into the food web. Further, the goby is emerging as a new predator on the eggs and young of small mouth bass.

Return of Blue-Green Algae

Following the success of phosphorus abatement programs in the 1970s and subsequent disappearance of unwanted algal blooms, it appears that some species of blue-green algae may be returning to parts of Lake Erie. *Microcystis aeruginosa* is capable of producing toxins that can harm the Lake's ecosystem and humans. Algal blooms that occurred in 1995 and 1998 were significantly smaller than those in the 1970s, although they were still unanticipated considering the 60% reduction in phosphorus inputs to the lake. It is thought that zebra mussels are concentrating phosphorus on the bottom of the Lake, thus allowing for the increased growth of *Microcystis*. The increased clarity of the water (also partially due to zebra mussels) allows light to penetrate to the bottom of the Lake and initiate an algal bloom.

Walleye Feeding Behaviour

Walleye populations appear stable in the Western basin with moderate abundance levels reported. They may have modified their feeding behaviour in response to increased water clarity as they seem to be feeding more at night. This makes the species less vulnerable to fishing during the day and could lead to an overall decrease in fishing pressure or possibly an increase in night fishing. Preliminary observations suggest that the former may be true.

Yellow Perch

There is evidence that the yellow perch may be recovering from low levels caused by reproductive failure in the late 1980s and early 1990s. There were good hatches reported in 1994 and 1996, poor hatches in 1995 and 1997 and preliminary data suggest a moderate hatch in 1998. It is hoped that when the young from the 1996 hatch reach reproductive age, yellow perch abundance will show even an greater increase.

Return of the Burrowing Mayfly

The return of the burrowing mayfly (*Hexagenia*) in the Western basin of Lake Erie is a positive indication of improved water quality in the lake. Burrowing mayflies are large aquatic insects that spend most of their two year lives in their larval form, living in shallow bottom sediments of lakes. Once numbering hundreds of individuals per square metre, populations decreased dramatically in the 1950s due to deteriorating water quality. Throughout most of the next three decades burrowing mayflies were virtually absent from their former Great Lakes habitat. Over the past five years U.S. and Canadian biologists have seen a dramatic resurgence of the mayfly in Lake Erie with numbers almost as high as they were in the early 20th century. This is good news for the entire Lake ecosystem as the mayfly is an important link in the food chain and their burrowing action resuspends nutrients necessary for plant growth. The indicator "Walleye and Hexagenia" addresses the abundance, biomass and annual production of both walleye and burrowing mayfly populations in historical, warm-coolwater, mesotrophic habitats of the Great Lakes (Appendix 1).

3.2.5 Lake Ontario

Beneficial Use Impairment Status

In May of 1998, the Lake Ontario LaMP identified the beneficial use impairments that exist lakewide in Lake Ontario, and the chemical, physical, and biological causes of these impairments (Table 5).

Table 5. Lake Ontario Lakewide Beneficial Use Impairments.

Lakewide Beneficial Use Impairments	Lakewide Critical Pollutants and Other Factors causing Impairments
Restrictions on fish and wildlife consumption	PCBs, dioxins, mirex, mercury, DDT
Degradation of wildlife populations	PCBs, dioxin, DDT
Bird or animal deformities or reproductive problems	PCBs, dioxin, DDT
Loss of fish and wildlife habitat	Lake level management, exotic species, physical loss, modification and destruction of habitat

Source: Lake Ontario LaMP, 1999

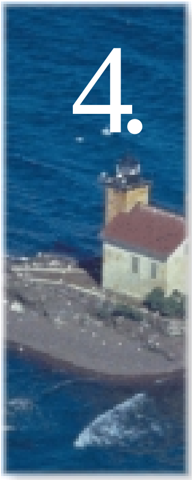
Signs of Improvement

Improvements in the Lake Ontario ecosystem resulting from the cooperation of the LaMP, RAPs, and many other programs can be seen throughout the lake ecosystem. For example, herring gull populations are fully recovered from DDT and PCB induced reproductive problems. The bald eagle is also showing signs of recovery as nesting territories have steadily grown from two nests in 1984 to eight nests in 1999. Fisheries are also showing positive signs with evidence of naturally reproducing lake trout emerging, as well as the gradual return of lake sturgeon, lake herring and deep water sculpin.

However, there are still areas that require improvement. Contaminant levels continue to impair beneficial uses, and existing problems of exotic species and habitat loss continue.

Diporeia Decline

Populations of benthic organisms in Lake Ontario have declined significantly since the 1960s creating major concern for Canadian and U.S. researchers. The invasion of quagga and zebra mussels to the Lake has resulted in major changes to native benthic species. One of the most significant is seen in population changes of *Diporeia* – a small shrimp-like organism. Historically, this species has made up more than 50% of the benthic population in Lake Ontario with numbers into the thousands per square metre. Today, less than 10 *Diporeia* individuals can be found per square metre, possibly an indication of the impact of quagga and zebra mussels. The Indicator "Lake Trout and Scud (*Diporeia hoyi*)" addresses the status and trends in *Diporeia* populations throughout the Great Lakes basin (Appendix 1).



4. Biodiversity Investment Areas

Biodiversity Investment Areas (BIAs) are a concept intended to recognize the importance of protecting the rich biological diversity of the Great Lakes ecosystem and the many kinds of habitat needed to support that diversity. The concept is also intended to provide a locally based recognition and support for areas of key biological importance, whether relatively undisturbed, or degraded. Such areas play a key role in maintaining the integrity of the ecosystem and its long term viability. The idea is not that some areas can be written off as not being important, but that some areas are of such importance that special efforts are needed to ensure preservation.

Historically, much effort has been devoted to stopping and cleaning up pollution in the most degraded areas of the system. Although this important work is still underway, there is a pressing need to address the protection of biological resources through protection of habitat and preventing degradation of key areas.

An example of the impact of habitat loss on biodiversity was the loss of all lake trout populations that reproduced in Great Lakes tributaries. Those genetic resources are gone from the earth. However, the Great Lakes ecosystem still contains rich reservoirs of native species and genetic variation developed over vast periods of time as native species adapted to the dynamic climate and other conditions in the ecosystem. Protection of that diversity is an important aspect of maintaining ecosystem integrity.

Biodiversity Investment Areas are *broad coastal areas that contain clusters of exceptional biodiversity values.* They highlight sections of Great Lakes shoreline that sustain rare and diverse plant and animal communities, and landscape features of special quality. Protecting the ecological richness of these areas is an essential facet of maintaining the integrity of the Great Lakes basin ecosystem.

The Great Lakes basin is one of the most productive economic systems in the world, fully dependent on invaluable natural resources and fragile ecological relationships. The Lakes and their watersheds are rich in aquatic life, sand beaches and sand dunes, forests, wetlands, lakeplain prairies, oak savannas, bedrock and cobble beaches, specialized limestone habitats called alvars, more than 30,000 islands, productive wetlands and offshore fish habitat. Over 130 globally rare communities and species unique to the basin are found here. The integrity of the ecosystem is in part dependent on the health of all the life and supporting habitat. As such, it is important to protect and restore biodiversity and the landscape associated with it.

The Biodiversity Investment Area concept was introduced in the SOLEC 96 background paper, Land by the Lakes, as a construct to assess the health of the combination of special lakeshore communities such as sand dunes and bedrock shores that are in the same general locale. Land by the Lakes detailed the status of nearshore terrestrial ecosystems, the stressors affecting its health, and the stewardship activities counteracting those stressors. The conclusion was that nearshore terrestrial ecosystems are degrading throughout the Great Lakes.

This conclusion served to focus attention on BIAs, areas that are of unusual biological significance and in need of protection from human impacts, as well as on areas that may have been altered from their original state, yet retain remnant natural areas and ecological values of exceptional significance. The phrase "biodiversity investment areas" was coined as a positive reminder that actions to protect biodiversity are an investment in the future of the region.

Most BIAs cover relatively undisturbed high quality areas, but even those areas include degraded sub-areas. In some cases, such as southwestern Lake Michigan, high priority resources exist in an area that is heavily degraded. In both cases restoration of high priority sub-areas may be important on their own merit, or to connect or buffer existing high quality remnants. In all cases, the challenge is to provide for the long term sustainability of all components of the Great Lakes basin ecosystem.

Twenty nearshore terrestrial biodiversity investment areas were identified for SOLEC 96. The identification of these areas does not mean there are no other outstanding areas of biodiversity in the basin. Numerous other high quality, but smaller, areas exist. However, nearshore terrestrial BIAs present key opportunities to create large, protected areas that will preserve ecological integrity and, ultimately, help protect the health of the Great Lakes themselves.

Because most BIAs are in relatively good ecological condition, they are often by-passed by agencies allocating resources in favor of places needing extensive remediation. If few resources are put into protecting areas that are relatively intact, they will very soon suffer from the same stresses as those places which are heavily damaged.

The stresses to BIAs are already severe and include the chemical and biological pollutant stressors mentioned above. Today, however, the major stress to ecological communities and biodiversity along the nearshore is development. Second homes, marinas, commercial and industrial development destroy habitat and, as a consequence, biodiversity.

For SOLEC 98, an expanded look at nearshore terrestrial BIAs further characterized their features and values, threats to biodiversity, protection measures in place, and key protection and restoration needs. An attempt was made to assess their ecological health. Attention to these areas should result in an increase in on-the-ground protection and restoration activities.

Identifying nearshore terrestrial BIAs for SOLEC 96, resulted in expansion of the idea for coastal wetlands and nearshore aquatic areas for SOLEC 98. The approach to identifying coastal wetland BIAs differed considerably. Stopping short of labeling areas as BIAs, coastal reaches (eco-reaches) that support significant wetland types that are ecologically distinctive and that are known to be exceptionally important habitat for a large number of fish and bird species were delineated. Additional work is needed to create a GIS-based inventory of all coastal wetlands and to develop a consistent terminology for classifying and describing coastal wetland types.

A start was made in identifying Great Lakes aquatic biodiversity investment areas (ABIAs) for SOLEC 98. The working definition for ABIA used in this study differs slightly from the terrestrial definition. Aquatic biodiversity investment areas are specific locations or areas within a larger ecosystem that are especially productive, support exceptionally high biodiversity and/or species found somewhere else, and contribute significantly to the integrity of the whole ecosystem. This definition encompasses consideration of centers of high levels of natural, self-sustaining productivity and ecological integrity of ecosystems as envisaged in the successive versions of the Great Lakes Water Quality Agreement.

The designation of Biodiversity Investment Area has great potential. The BIA concept is a vision of the healthy areas of the Great Lakes basin which contrasts with our images of polluted landscapes. BIAs are rich with examples of healthy plants and animals living in functioning ecosystems. They are the pieces of the puzzle needed to make good and protective land use decisions. They are our historic and ecological repositories for future exploration. They are our outdoor classrooms, complete with learning adventures.

SOLEC 96 and 98 introduced the Biodiversity Investment Area concept in order to focus attention on natural resources which distinguish the Great Lakes as one of the world's most unique ecosystems. The concept is not fully developed, nor have BIA designations been clarified basin-wide. The following steps are needed to refine the process for BIA designation and to introduce the results to the people of the Great Lakes.

1. The process of identifying potential BIAs needs a general over-arching classification system in which the different classes of BIAs can be interlocked and nested. This is essential in order for the governments, their non-governmental partners, and the International Joint Commission to set priorities for securement.
2. The three BIA approaches need to be merged into a single set of coastal BIAs
3. Aquatic BIAs identified for SOLEC 98 need further refinement with input from additional resource managers. A consistent wetlands classification system is needed in order to understand their complexity, measure their health and incorporate them into the BIA scheme.
4. All BIAs are in need of locally-based assessments to identify the most important biological communities and species, physical features and sites, key processes supporting biodiversity, key stressors affecting biodiversity, and conditions needed to protect ecosystem integrity.
5. Ways to implement the BIA concept through actions by LaMPs, Federal, state/provincial, local government bodies, the IJC etc. need to be examined.
6. Prior to SOLEC 2000, a workshop for resource managers and interested parties to work through the above recommendations would validate and lend credence to the BIA concept.

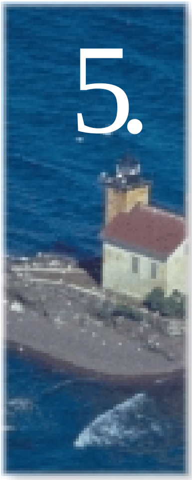
The BIA concept includes the potential of stimulating local people and organizations to become invested in and identify with the biodiversity of their area and the habitat that supports it. Increased awareness can provide a powerful incentive to support protection and restoration of local ecosystems. While no formal process such as that for RAPs or LaMPs is envisioned, highly visible assessment of the areas and identification of needed actions can provide substantial incentive for locally supported protection.

Biodiversity Investment Areas are the benchmarks against which we measure progress towards ecosystem health. Together, maps of the richest and most degraded areas of the basin direct us to act. We must protect the ecological integrity of the basin's resources and restore that which we have damaged back to health.

For further information on the BIA concept please see the following reports,

- Nearshore Terrestrial Ecosystems
- Coastal Wetland Ecosystems, Identification of "Eco-Reaches" of Great Lakes Coastal Wetlands that have high biodiversity value
- Aquatic Ecosystems - Aquatic Biodiversity Investment Areas in the Great Lakes Basin: Identification and Validation

These reports are available for viewing or downloading from the SOLEC web sites:
www.cciw.ca/solec/ or www.epa.gov/glnpo/solec/98/



5. Conclusions and Challenges

Based on the 19 indicators and other information presented in this report we can say that:

- Exotic Species: Exotic species continue to stress the ecosystem. Although much work has already been done on the control of sea lamprey, these programs will likely be on-going for many years to come. The complete impact of zebra mussels is unknown — we do know that they have caused the decline of the diversity and density of native clam populations at certain sites and that they are impacting the food web and the cycling of contaminants within the food web. The round goby is yet another non-native species to become established in the Lakes, and could pose a threat to the integrity of the biological community in the Great Lakes.

- Nutrients: Phosphorus concentrations in the Lakes in most cases are at or below the proposed targets, however, strict loading targets must be adhered to as the human population in the basin increases.

- Atmosphere: The atmosphere is an important route for the input of toxic contaminants to the Great Lakes system — some of which originate from outside the Great Lakes basin. Of the organochlorine insecticides discussed in this report, the concentrations of lindane and ß-endosulfan in precipitation have increased in recent years at the sampling sites.

- Atmosphere: Acid rain continues to be a problem in the basin — mainly to the areas on the Canadian shield. Although decreases of 30% and 54% of sulphur dioxide have been seen in recent years in the U.S. and Canada respectively, rain is still acidic throughout most of the region and is likely to remain that way over the coming decade.

- Biodiversity and Bird Populations: The peregrine falcon is an endangered species that appears to be making a comeback, in 1997 there were over 120 pairs in the basin. The population of the giant Canada goose, once thought to have been extinct, has exploded and is now considered a nuisance species in the basin. The double-crested cormorant is another species that was near extinction a few decades ago but has now increased by 300 times to over 38,000 pairs.

- Biodiversity and Wetlands: Populations of wetland-nesting bird species, such as the Black Tern and American Bittern, are declining. The exact reasons are not known, but habitat loss in coastal wetlands could be a cause.

- Coastal Wetlands: While the total coastal wetland area is decreasing within the Great Lakes basin, there have been some successful wetland restoration efforts. Effective restoration must take into consideration the quality and type of the original wetland. It may take several years for the wetland to become established and to function as it did previously.

- Coastal Wetlands: The quality of coastal wetlands is being impacted by altered sediment loads caused mainly by human activities. In a study of sediment loadings to Canadian coastal wetlands around Lake St. Clair (1990-1996) it was found that loadings for all years were high relative to rates for other Great Lakes wetland watersheds. This is in part due to the intensive agriculture that takes place in the St. Clair watersheds.

- Terrestrial: The health of the nearshore terrestrial environment continues to degrade - with stressors of human settlement, industry and even recreation.

- Land Use: The agriculture community has recognized the impact they make on the environment and is adopting farming practices that are economically viable, environmentally sound and socially responsible. Since 1993 there have been 7,892 Environmental Farm Plans approved in Ontario — these are plans to identify and remediate environmental areas of concern on the farms.

- Stewardship: There are many other examples of successful stewardship and restoration in the basin and the Remedial Action Plans for the Great Lakes Areas of Concern continue to be developed and implemented.

- Human Health: Human health is affected by the state of the surrounding environment with many sub-populations at greater potential risk due to various contaminants, including infants and elderly people, sportfishers, pregnant women, and tribal peoples. Fish consumption advisories still exist in all the Great Lakes due to various contaminants in the fish. The air quality in the basin causes health threats to susceptible populations — Canadian data show a correlation between an increase in ground level ozone and an increase in the number of daily hospital admissions due to respiratory conditions. However, concentrations of many contaminants in human tissue (such as blood, breast milk, hair, urine and fatty tissue) have declined over the past few decades. There is also the issue of microbial contamination — beaches may be closed in the basin due to elevated levels of bacteria. In 1996, 6 out of 50 sampled public beaches on the Canadian side of Lake Erie had median values of *E. coli* above the Ontario guideline.

Additionally, there are changes in stresses and the effects of combined stresses in the lakes that are translating into shifts in the aquatic community (especially prey species). This will sometimes create an opportunity for a return to native species and possibly communities-of-old and other times will cause replacement of native species with non-native species.

The State of the Great Lakes reporting in the near future will need to continue to improve its reporting on the Lakes in terms of ecosystem integrity, especially the health of its living resources, including humans. The challenge will be to develop and report on indicators that provide reliable measures of ecological health including the many ecological communities that constitute the living resources of the Great Lakes basin ecosystem. The major long term question is whether the communities are in an adequate state of health, supported by environmental conditions that will sustain them on a permanent basis. By maintaining a focus on these aspects, State of the Great Lakes reporting can contribute to attaining ecological integrity.

The suite of indicators discussed in this report can be used by the governments of Canada and the U.S. not only as a basis for reporting on progress, but also as a focus for monitoring and research. Several challenges lie ahead to achieve these objectives, including:

- Reviewing, refining and completing the proposed indicator list;

- Gaining acceptance of the list by federal, state, and provincial partners with the potential to monitor these indicators;

- Nesting local and lake-wide indicators within basin-wide indicators;

- Building appropriate monitoring and reporting activities into Great Lakes programs at the federal, provincial, state, Tribes / First Nations, and industry levels, including agencies that have not traditionally provided monitoring data;

- Reporting on selected indicators at SOLEC 2000 in a format that will meet the needs of many parties. As we are able to provide more detailed information, more audiences can be served including the general public, local decision makers and the scientific and engineering community.

In addition, the Biodiversity Investment Areas, a concept first presented in 1996 at the State of the Lakes Ecosystem Conference, need to be refined through additional research and monitoring where appropriate. The designation of Biodiversity Investment Area has great potential — including the potential of stimulating local people and organizations to become invested in and identify with the biodiversity of their area and the habitat that supports it. The BIA concept is a vision of the healthy areas of the Great Lakes basin which contrasts with our images of polluted landscapes. BIAs are our historic and ecological repositories for future exploration. The real challenge will be to secure local commitment to protect these areas, in whatever form that protection may take.

The following overall qualitative assessment can be provided: The state of the Great Lakes in 1999 has not changed significantly from the state reported on in 1997. With respect to herring gull eggs, analyses show that most contaminants at most sites are continuing to decline at a rate similar to that over the last decade or two. The Parties also note that the emergence of the round goby as yet another non-native species to become established in the Lakes, could pose a threat to the integrity of the biological community in the Great Lakes.

Appendix 1 — Brief Description of the Indicators List

Note: The numbers following the indicator name are a means of identifying the indicator in the electronic database.

Open and Nearshore Waters Indicators

State Indicators

Aquatic Habitat (Indicator #0006)

This indicator will assess the quality and amount of aquatic habitat in the Great Lakes ecosystem, and it will be used to infer progress in rehabilitating degraded habitat and associated aquatic communities.

Salmon and Trout (Indicator #0008)

This indicator will show trends in populations of introduced trout and salmon populations, and it will be used to evaluate the potential impacts on native trout and salmon populations and the preyfish populations that support them.

Walleye and *Hexagenia* (Indicator #0009)

This indicator will show the status and trends in walleye and *Hexagenia* populations, and it will be used to infer the basic structure of warm-coolwater predator and prey communities, the health of percid populations, and the health of the Great Lakes ecosystem.

Preyfish Populations (Indicator #0017)

This indicator will assess the abundance and diversity of preyfish populations, and it will be used to infer the stability of predator species necessary to maintain the biological integrity of each lake.

Native Unionid Mussels (Indicator #0068)

This indicator will assess the population status of native Unionid populations, and it will be used to infer the impact of the invading Dreissenid mussel on the Unionid mussel.

Lake Trout and Scud (*Diporeia hoyi*) (Indicator #0093)

This indicator will show the status and trends in lake trout and *D. hoyi* populations, and it will be used to infer the basic structure of coldwater predator and prey communities and the general health of the ecosystem.

Deformities, Erosion, Lesions and Tumors in Nearshore Fish (Indicator #0101)

This indicator will assess the combination of deformities, eroded fins, lesions and tumors (DELT index) in nearshore fish, and it will be used to infer areas of degraded habitat within the Great Lakes.

Benthos Diversity and Abundance (Indicator #0104)

This indicator will assess species diversity and abundance in the aquatic oligochaete community, and it will be used to infer the relative health of the benthic community.

Phytoplankton Populations (Indicator #0109)

This indicator will assess the species and size composition of phytoplankton populations in the Great Lakes, and it will be used to infer the impact of nutrient enrichment, contamination and invasive exotic predators on the Great Lakes ecosystem.

Zooplankton Populations (Indicator #0116)

This indicator will assess characteristics of the zooplankton community, and it will be used over time to infer changes in vertebrate or invertebrate predation, system productivity, energy transfer within the Great Lakes, or other food web dynamics.

Pressure Indicators

Sea Lamprey (Indicator #0018)

This indicator will estimate sea lamprey abundance and assess their impact on other fish populations in the Great Lakes.

Fish Entrainment (Indicator #0072)

This indicator will reflect the water withdrawal rates at once-through cooling systems at steam-electric and pumped-storage power plants in the Great Lakes and connecting channels, and it will be used to estimate site-specific entrainment mortality of fishes and an annual, aggregated, basin-wide estimate.

Phosphorus Concentrations (Indicator #0111)

This indicator will assess the total phosphorus levels in the Great Lakes, and it will be used to support the evaluation of trophic status and food web dynamics in the Great Lakes.

Contaminants in Recreational Fish (Indicator #0113)

This indicator will assess the levels of PBT chemicals in fish, and it will be used to infer the potential harm to human health through consumption of contaminated fish.

Contaminants in Young-of-the-Year Spottail Shiners (Indicator #0114)

This indicator will assess the levels of PBT chemicals in young-of-the-year spottail shiners, and it will be used to infer local areas of elevated contaminant levels and potential harm to fish-eating wildlife.

Contaminants in Colonial Nesting Waterbirds (Indicator #0115)

This indicator will assess chemical concentration levels in a representative colonial waterbird, and it will be used to infer the impact of these contaminants on colonial waterbird physiology and population characteristics.

Atmospheric Deposition of Toxic Chemicals (Indicator #0117)

This indicator will estimate the annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes, and it will be used to infer potential impacts of toxic chemicals from atmospheric deposition on the Great Lakes aquatic ecosystem, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Toxic Chemical Concentrations in Offshore Waters (Indicator #0118)

This indicator will assess the concentration of priority toxic chemicals in offshore waters, and it will be used to infer the potential impacts of toxic chemicals on the Great Lakes aquatic ecosystem, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Concentrations of Contaminants in Sediment Cores (Indicator #0119)

This indicator will assess the concentrations of IJC priority toxic chemicals in sediments, and it will be used to infer potential harm to aquatic ecosystems by contaminated sediments, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Contaminant Exchanges between Media: Air to Water and Water to Sediment (Indicator #0120)

This indicator will estimate the loadings of IJC priority pollutants to the Great Lakes, and it will be used to infer the potential harm these contaminants pose to human, animal and aquatic life within the Great Lakes, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Coastal Wetland Indicators

State Indicators

Coastal Wetland Invertebrate Community Health (Indicator #4501)

This indicator will assess the diversity of the invertebrate community, especially aquatic insects, and it will be used to infer habitat suitability and biological integrity of Great Lakes coastal wetlands.

Coastal Wetland Fish Community Health (Indicator #4502)

This indicator will assess the fish community diversity, and it will be used to infer habitat suitability for Great Lakes coastal wetland fish communities.

Deformities/Eroded Fins/Lesions/Tumours (DELT) in Coastal Wetland Fish (Indicator #4503)

This indicator will assess the combination of deformities, eroded fins, lesions and tumors (DELT index) in coastal wetlands, and it will be used to infer ecosystem health of Great Lakes coastal wetlands.

Amphibian Diversity and Abundance (Indicator #4504)

This indicator will assess the species composition and relative abundance of frogs and toads, and it will be used to infer the condition of coastal wetland habitat as it relates to the health of this ecologically important component of wetland communities.

Wetland-Dependent Bird Diversity and Abundance (Indicator #4507)

This indicator will assess the wetland bird species composition and relative abundance, and it will be used to infer the condition of coastal wetland habitat as it relates to the health of this ecologically and culturally important component of wetland communities.

Coastal Wetland Area by Type (Indicator #4510)

This indicator will assess the periodic changes in area (particularly losses) of coastal wetland types, taking into account natural variations.

Gain in Restored Coastal Wetland Area by Type (Indicator #4511)

This indicator will assess the amount of restored wetland area, and it will be used to infer the success of conservation and rehabilitation efforts.

Presence, Abundance and Expansion of Invasive Plants (Indicator #4513)

This indicator will assess the decline of vegetative diversity associated with an increase in the presence, abundance, and expansion of invasive plants, and it will be used as a surrogate measure of the quality of coastal wetlands which are impacted by coastal manipulation or input of sediments.

Habitat Adjacent to Coastal Wetlands (Indicator #7055)

This indicator will provide an index of the quality of adjoining upland habitat which can have a major effect on wetland biota, many of which require upland habitat for part of their life cycle.

Pressure Indicators

Contaminants in Snapping Turtle Eggs (Indicator #4506)

This indicator will assess the accumulation of organochlorine chemicals and mercury in snapping turtle eggs, and it may be used to infer the extent of organochlorine chemicals and mercury in food webs of Great Lakes coastal wetlands.

Sediment Flowing into Coastal Wetlands (Indicator #4516)

This indicator will assess the sediment load to coastal wetlands and its potential impact on wetland health.

Nitrates and Total Phosphorus Into Coastal Wetlands (Indicator #4860)

This indicator will assess the amount of nitrate and total phosphorus flowing into Great Lakes coastal wetlands, and it will be used to infer the human influence on nutrient levels in the wetlands.

Water Level Fluctuations (Indicator #4861)

This indicator will assess the lake level trends that may significantly affect components of wetland and nearshore terrestrial ecosystems, and it will be used to infer the effect of water level regulation on emergent wetland extent.

Nearshore Terrestrial Indicators (within 1 kilometer of shore)

State Indicators

Indicators related to habitats:

Extent and Quality of Nearshore Natural Land Cover (Indicator #8136)

This indicator will assess the amount of natural land cover that falls within 1 km of the shoreline, and it will be used to infer the potential impact of artificial coastal structures, including primary and secondary home development, on the extent and quality of nearshore terrestrial ecosystems in the Great Lakes.

Indicators related to health and stability of ecological communities/species:

Area, Quality, and Protection of Special Lakeshore Communities (Indicator #8129)

This indicator will assess the changes in area and quality of the twelve special lakeshore communities, and it will be used to infer the success of management activities associated with the protection of some of the most ecologically significant habitats in the Great Lakes terrestrial nearshore.

Nearshore Species Diversity and Stability (Indicator #8137)

This indicator will assess the composition and abundance of plant and wildlife species over time within the nearshore area, and it will be used to infer adverse effects on the nearshore terrestrial ecosystem due to stresses such as climate change and/or increasing land use intensity.

Pressure Indicators

Indicators related to physical stressors:

Water Level Fluctuations (Indicator #4861) - *this is also a Coastal Wetland indicator*

This indicator will assess the lake level trends that may significantly affect components of wetland and nearshore terrestrial ecosystems, and it will be used to infer the effect of water level regulation on emergent wetland extent.

Extent of Hardened Shoreline (Indicator #8131)

This indicator will assess the amount of shoreline habitat altered by the construction of shore protection, and it will be used to infer the potential harm to aquatic life in the nearshore as a result of conditions (e.g., shoreline erosion) created by habitat alteration.

Nearshore Land Use Intensity (Indicator #8132)

This indicator will assess the types and extent of major land uses within 1 km from shore, and it will be used to identify real or potential impacts of land use on significant natural features or processes, particularly on the twelve special lakeshore communities.

Artificial Coastal Structures (Indicator #8146)

This indicator will assess the number of artificial coastal structures on the Great Lakes, and it will be used to infer potential harm to coastal habitat by disruption of sand transport.

Indicators related to biological stressors:

Nearshore Plant and Wildlife Problem Species (Indicator #8134)

This indicator will assess the type and abundance of plant and wildlife problem species in landscapes bordering the Great Lakes, and it will be used to identify the potential for disruption of nearshore ecological processes and communities.

Indicators related to chemical stressors:

Contaminants Affecting Productivity of Bald Eagles (Indicator #8135)

This indicator will assess the number of fledged young, number of developmental deformities, and the concentrations of organic and heavy metal contamination 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.

Contaminants Affecting the American Otter (Indicator #8147)

This indicator will assess the contaminant concentrations found in American otter populations within the Great Lakes basin, and it will be used to infer the presence and severity of contaminants in the aquatic food web of the Great Lakes.

Human Activities (Response) Indicators

Community / Species Plans (Indicator #8139)

This indicator will assess the number of plans that are needed, developed, and implemented to protect, maintain or restore high quality, natural nearshore communities and federally listed endangered, threatened, and vulnerable species. This indicator will be used to infer the degree of human stewardship toward these communities and species.

Shoreline Management Under Integrated Management Plans (Indicator #8141)

This indicator will assess the amount of Great Lakes shoreline managed under an integrated management plan, and it will be used to infer the degree of stewardship of shoreline processes and habitat.

Nearshore Protected Areas (Indicator #8149)

This indicator will assess the kilometers/miles of shoreline in six classes of protective status. This information will be used to infer the preservation and restoration of habitat and biodiversity, the protection of adjacent nearshore waters from physical disturbance and undesirable inputs (nutrients and toxics), and the preservation of essential habitat links in the migration (lifecycle) of birds and butterflies.

Land Use Indicators

State Indicators

Breeding Bird Diversity and Abundance (Indicator #8150)

This indicator will assess the status of breeding bird populations and communities, and it will be used to infer the health of breeding bird habitat in the Great Lakes basin.

Threatened Species (Indicator #8161)

This indicator will assess the number, extent and viability of threatened species, which are key components of biodiversity in the Great Lakes basin, and it will be used to infer the integrity of ecological processes and systems (e.g., sand accretion, hydrologic regime) within Great Lakes habitats.

Pressure Indicators

Urban Density (Indicator #7000)

This indicator will assess the human population density in the Great Lakes basin, and it will be used to infer the degree of inefficient land use and urban sprawl for communities in the Great Lakes ecosystem.

Land Conversion (Indicator #7002)

This indicator will assess the changes in land use within the Great Lakes basin, and it will be used to infer the potential impact of land conversion on Great Lakes ecosystem health.

Mass Transportation (Indicator #7012)

This indicator will assess the percentage of commuters using public transportation, and it will be used to infer the stress to the Great Lakes ecosystem caused by the use of the private motor vehicle and its resulting high resource utilization and pollution creation.

Habitat Fragmentation (Indicator #8114)

This indicator will assess the amount and distribution of natural habitat remaining within Great Lakes ecoregions, and it will be used to infer the effect of human land uses such as housing, agriculture, flood control, and recreation on habitat needed to support fish and wildlife species.

Stream Flow and Sediment Discharge (Indicator #8142)

This indicator will assess the amount of water and suspended sediment entering the Great Lakes through major tributaries and connecting channels, and it will be used to estimate the amount of sediment available for transport to nourish coastal ecosystems.

Human Activities (Response) Indicators

Brownfield Redevelopment (Indicator #7006)

This indicator will assess the acreage of redeveloped brownfields, and it will be used over time to evaluate the rate at which society rehabilitates and reuses former developed land sites that have been degraded by poor use.

Use of Sustainable Agriculture Practices (Indicator #7028)

This indicator will assess the number of Environmental and Conservation farm plans, and it will be used to infer environmentally friendly practices in place, such as integrated pest management to reduce the unnecessary use of pesticides, zero tillage and other soil preservation practices to reduce energy consumption, and prevention of ground and surface water contamination.

Green Planning Process (Indicator #7053)

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

Water Consumption (Indicator #7056)

This indicator will assess the amount of water used in the Great Lakes basin per capita, and it will be used to infer the amount of wastewater generated and the demand for resources to pump and treat water.

Energy Consumption (Indicator #7057)

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

Wastewater Pollution (Indicator #7059)

This indicator will assess the loadings of wastewater pollutants discharged into the Great Lakes basin, and it will be used to infer inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

Solid Waste Generation (Indicator #7060)

This indicator will assess the amount of solid waste generated per capita in the Great Lakes basin, and it will be used to infer inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

Human Health Indicators

State Indicators

Geographic Patterns and Trends in Disease Incidence (Indicator #4179)

This indicator will assess geographical and temporal patterns in disease incidences in the Great Lakes basin population, and it will also be used to identify areas where further investigation of the exposure and effects of environmental pollutants on human health is needed.

Pressure Indicators

Indicators of Exposure

Fecal Pollution Levels of Nearshore Recreational Waters (Indicator #4081)

This indicator will assess fecal coliform contaminant levels in nearshore recreational waters, acting as a surrogate indicator for other pathogen types, and it will be used to infer potential harm to human health through body contact with nearshore recreational waters.

Chemical Contaminants in Fish Tissue (Indicator #4083)

This indicator will assess the concentration of persistent, bioaccumulating, toxic (PBT) chemicals in Great Lakes fish, and it will be used to infer the potential exposure of humans to PBT chemicals through consumption of Great Lakes fish caught via sport and subsistence fishing.

Chemical Contaminant Intake From Air, Water Soil and Food (Indicator #4088)

This indicator will estimate the daily intake of PBT chemicals from all sources, and it will be used to evaluate the potential harm to human health and the efficacy of policies and technology intended to reduce PBT chemicals.

Drinking Water Quality (Indicator #4175)

This indicator will assess the chemical and microbial contaminant levels in drinking water, and it will be used to evaluate the potential for human exposure to drinking water contaminants and the efficacy of policies and technologies to ensure safe drinking water.

Air Quality (Indicator #4176)

This indicator will monitor the air quality in the Great Lakes ecosystem, and it will be used to infer the potential impact of air quality on human health in the Great Lakes basin.

Chemical Contaminants in Human Tissue (Indicator #4177)

This indicator will assess the concentration of PBT chemicals in human tissues, and it will be used to infer the efficacy of policies and technology to reduce PBT chemicals in the Great Lakes ecosystem.

Radionuclides (Indicator #4178)

This indicator will assess the concentrations of artificial radionuclides in cow's milk, surface water, drinking water, and air, and it will be used to estimate the potential for human exposure to artificial radionuclides.

Societal Indicators

State Indicators

Aesthetics (Indicator #7042)

This indicator will assess the amount of waste and decay around human activities in the Great Lakes basin, and it will be used to infer the degree to which human activities are conducted in an efficient and ordered fashion consistent with ecosystem harmony and integrity.

Economic Prosperity (Indicator #7043)

This indicator will assess the unemployment rates within the Great Lakes basin, and it will be used in association with other Societal indicators to infer the capacity for society in the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem.

Human Activities (Response) Indicators

Capacities of Sustainable Landscape Partnerships (Indicator #3509) - *unreviewed*

This indicator assesses the organizational capacities required of local coalitions to act as full partners in ecosystem management initiatives. It includes the enumeration of public-private partnerships relating to the pursuit of sustainable ecosystems through environmental management, staff, and annual budgets.

Organizational Richness of Sustainable Landscape Partnerships (Indicator #3510) - *unreviewed*

This indicator assesses the diversity of membership and expertise included in partnerships. Horizontal integration is a description of the diversity of partnerships required to address local issues, and vertical integration is the description of federal and state/provincial involvement in place-based initiatives as full partners.

Integration of Ecosystem Management Principles Across Landscapes (Indicator #3511) - *unreviewed*

This indicator describes the extent to which federal, state/provincial, and regional governments and agencies have endorsed and adopted ecosystem management guiding principles in place-based resource management programs.

Integration of Sustainability Principles Across Landscapes (Indicator #3512) - *unreviewed*

This indicator describes the extent to which federal, state/provincial, and regional governments and agencies have endorsed and adopted sustainability guiding principles in place-based resource management programs.

Citizen/Community Place-Based Stewardship Activities (Indicator #3513) - *unreviewed*

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

Financial Resources Allocated to Great Lakes Programs (Indicator #8140)

This indicator will assess the amount of dollars spent annually on Great Lakes programs, and it will be used to infer the responsiveness of Great Lakes programs through annual funding focused on research, monitoring, restoration, and protection of Great Lakes ecosystems by federal and state/provincial agencies and non-governmental organizations.

Unbounded Indicators

State Indicators

Atmospheric Visibility (Indicator #9001)

This indicator will assess the percentage of daylight hours with reduced visibility per year, and it will be used to infer the efficacy of policies and technologies developed to improve visibility in the Great Lakes basin.

Pressure Indicators

Acid Rain (Indicator #9000)

This indicator will assess the pH levels in precipitation and critical loadings of sulphate to the Great Lakes basin, and it will be used to infer the efficacy of policies to reduce sulphur and nitrogen acidic compounds released to the atmosphere.

Global Warming: Number of Extreme Storms (Indicator #4519)

This indicator will assess the number of "extreme storms" each year, and it will be used to infer the potential impact on ecological components of the Great Lakes of increased numbers of severe storms due to climate change.

Global Warming: First Emergence of Water Lilies in Coastal Wetlands (Indicator #4857)

This indicator will assess the change over time in first emergence dates of water lilies in coastal wetlands as a sentinel of climate change affecting the Great Lakes.

Global Warming: Ice Duration on the Great Lakes (Indicator #4858)

This indicator will assess the temperature and accompanying physical changes to each lake over time, and it will be used to infer potential impact of climate change on wetlands.

Appendix 2 — How Relavant are the Indicators?

The list of indicators was developed according to the categories of open and nearshore waters, coastal wetlands, nearshore terrestrial, human health, land use, societal and unbounded. These groupings are convenient for reporting, but they represent only one of many ways to organize information about the Great Lakes. Depending on the user's perspective, other groupings will be more convenient or will provide insight to aspects of the Great Lakes that differ from the SOLEC groupings.

Each of the proposed indicators has been evaluated by the SOLEC Indicators Group for relevance to several other organizational categories, and the results are displayed in the attached table. The categories include;

- Indicator Type. Based on the State-Pressure-Human Activity model, each indicator has been assigned to the appropriate category. Measurements of contaminants in an environmental compartment are considered a pressure on the ecosystem rather than a measurement of a state condition. There are currently 28 State, 37 Pressure and 15 Human Activity indicators proposed.

- Environmental Compartments. This category sorts the indicators by media, i.e., air (6), water (14), land (14), sediments (4), biota (21), fish (13), and humans (14). Fish have been separated from biota as a special case.

- Issues. Environmental management decisions often reflect an attempt to address an issue rather than a medium or geographic location. Specific issues that the indicators support include toxic contaminants (29), nutrients (12), exotic species (8), habitat (28), climate change (4), and stewardship (11).

- GLWQA Annexes. Several of the annexes of the GLWQA include monitoring and reporting requirements. The proposed indicators currently address 10 of the 17 annexes. Annex 11 (Monitoring) is supported if an indicator supports any of the other annexes, and Annex 2 (LaMPs and RAPs) is supported if the indicators address any of the Beneficial Use Impairments.

- GLWQA Beneficial Use Impairments. Under Annex 2 of the GLWQA, 14 Beneficial Use Impairments are listed for consideration by Lakewide Management Plans and Remedial Action Plans. The indicators address to some extent 11 of the 14 listed use impairments.

- IJC Desired Outcomes. The IJC listed nine Desired Outcomes in its report *Indicators to Evalutate Progress under the Great Lakes Water Quality Agreement* (1996). The indicators address to some extent all nine Desired Outcomes. The many indicators with relevance to the outcomes of Biological Community Integrity and Diversity, and Physical Environment Integrity (including habitat) reflect SOLEC's emphasis on the biotic components of the Great Lakes ecosystem.

- Great Lakes Fish Community Objectives. A series of fish community objectives have been released or are being developed for each of the Great Lakes with the support of the Great Lakes Fishery Commission. Some SOLEC indicators specifically reflect the state of fish communities, and others address related habitat issues.

While the indicators are intended to meet the criteria of necessary, sufficient and feasible for SOLEC reporting, no attempt has been made to evaluate the adequacy of the subset of indicators that are relevant to any of the alternate organizing categories from the perspective of other users. For example, LaMPs and RAPs are expected to require a greater level of detail and geographic specificity to assess Beneficial Use Impairments than will be provided by the proposed indicators. Suggestions and comments on the relevance of the indicators to these or other alternate categories are encouraged.

ID#	Indicator name	Indicator Type			Environmental Compartments							Issues						SOLEC Groups	
		State	Pressure	Human Activity	Air	Water	Land	Sediments	Biota	Fish	Humans	Toxics	Nutrients	Exotics	Habitat	Climate Change	Stewardship	Open Waters	Nearshore Waters
6	Aquatic Habitat	x				x									x			x	x
8	Salmon and Trout	x								x		x	x	x	x			x	x
9	Walleye and Hexagenia	x							x	x		x	x		x			x	x
17	Preyfish Populations	x								x		x	x	x	x			x	x
18	Sea Lamprey		x							x				x				x	x
68	Native Unionid Mussels	x							x					x				x	x
72	Fish Entrainment		x							x					x			x	x
93	Lake Trout and Scud (Diaporeia hoyi)	x							x	x		x	x	x	x			x	
101	Deformities, Erosion, Lesions and Tumors in Nearshore Fish	x								x		x						x	x
104	Benthos Diversity and Abundance	x							x			x	x		x			x	x
109	Phytoplankton Populations	x							x			x	x					x	x
111	Phosphorus Concentrations and Loadings		x			x							x					x	x
113	Contaminants in Recreational Fish		x							x		x						x	x
114	Contaminants In Young-of-the-Year Spottail Shiners		x							x		x							x
115	Contaminants in Colonial Nesting Waterbirds		x						x			x						x	x
116	Zooplankton Populations	x							x			x	x					x	x
117	Atmospheric Deposition of Toxic Chemicals		x		x	x						x						x	
118	Toxic Chemical Concentrations in Offshore Waters		x			x						x						x	
119	Concentrations of Contaminants in Sediments Cores		x					x				x						x	
120	Contaminant Exchange Between Air to Water & Water to Sediment		x		x	x		x				x						x	
3509	Capacities of Sustainable Landscape Partnerships			x							x						x		
3510	Organizational Richness of Sustainable Landscape Partnerships			x							x						x		
3511	Integration of ecosystem management principles across landscapes			x							x						x		
3512	Integration of Sustainability Principles Across Landscapes			x							x						x		
3513	Citizen/Community Place-Based Stewardship Activities			x							x						x		
4081	Fecal Pollution Levels of Nearshore Recreational Waters		x			x						x	x						x
4083	Chemical Contaminants in Fish Tissue		x							x		x						x	x
4088	Chemical Contaminant Intake from Air, Water, Soil and Food		x								x	x							
4175	Drinking Water Quality		x			x						x	x						x
4176	Air Quality		x		x							x							
4177	Chemical Contaminants in Human Tissue		x								x	x							
4178	Radionuclides		x		x	x						x							
4179	Geographic Patterns and Trends in Disease Incidence	x									x								
4501	Coastal Wetland Invertebrate Community Health	x							x						x				
4502	Coastal Wetland Fish Community Health	x								x					x				
4503	Deformities/Eroded Fins/Lesions/Tumors (DELT) in Fish	x								x		x							
4504	Amphibian Diversity and Abundance	x							x						x				
4506	Contaminants in Snapping Turtle Eggs		x						x			x							
4507	Wetland-dependent Bird Diversity and Abundance	x							x						x				
4510	Coastal Wetland Area by Type	x					x								x				
4511	Gain in Restored Coastal Wetland Area by Type	x					x								x				
4513	Presence, Abundance & Expansion of Invasive Plants	x							x						x				
4516	Sediment Flowing Into Coastal Wetlands		x			x		x							x				x
4519	Global Warming: Number of Extreme Storms		x													x			
4857	Global Warming: 1st Emergence of Water Lilies in Coastal Wetlands		x						x							x			
4858	Global Warming: Ice Duration on the Great Lakes		x													x			x
4860	Nitrates and Total Phosphorus Into Coastal Wetlands		x			x							x						
4861	Water Level Fluctuations		x			x									x	x			
7000	Urban Density		x				x												
7002	Land Conversion		x				x												
7006	Brownfield Redevelopment			x			x												
7012	Mass Transportation		x				x												
7028	Sustainable Agricultural Practices			x			x												
7042	Aesthetics	x									x								
7043	Economic Prosperity	x																	
7053	Green Planning Process			x															
7055	Habitat Adjacent to Coastal Wetlands	x				x						x	x		x				x
7056	Water Consumption			x							x						x		
7057	Energy Consumption			x							x						x		
7059	Wastewater Pollutant Loading		x			x						x							x
7060	Solid Waste Generation			x							x						x		
8114	Habitat Fragmentation		x				x								x				
8129	Area, Quality, and Protection of Special Lakeshore Communities	x							x						x				
8131	Extent of Hardened Shoreline		x				x								x				
8132	Nearshore Land Use Intensity		x				x								x				
8134	Nearshore Plant and Wildlife Problem Species		x						x					x	x				
8135	Contaminants Affecting Productivity of Bald Eagles		x						x			x						x	x
8136	Extent and Quality of Nearshore Natural Land Cover	x					x								x				
8137	Nearshore Species Diversity and Stability	x							x					x	x				
8139	Community / Species Plans			x					x								x		
8140	Financial Resources Allocated to Great Lakes Programs			x							x						x		
8141	Shoreline Managed Under Integrated Management Plans			x			x				x						x		
8142	Streamflow		x			x		x							x				x
8146	Artificial Coastal Structures		x				x								x				
8147	Contaminants Affecting the American Otter		x						x			x							
8149	Nearshore Protected Areas			x			x								x				
8150	Breeding Bird Diversity and Abundance	x							x										
8161	Threatened Species	x							x	x				x	x			x	x
9000	Acid Rain		x		x							x							
9001	Atmospheric Visibility: Prevention of Significant Deterioration	x			x														
80	COUNT	28	37	15	6	14	14	4	21	13	14	29	12	8	28	4	11	22	25

ID#	Indicator name	SOLEC Groupings (con'd)						GLWQA Annex											
		Coastal Wetlands	Nearshore Terrestrial	Land Use	Human Health	Societal	Unbounded	1 Spec Objctvs	2 LaMPs RAPs BUIs	3 Phosphorus	4 Oil - Vessels	5 Wastes - Vessels	6 Shipping/ Pollution	7 Dredging	8 Facilities	9 Contingency Plan	10 Hazard. Poll. List	11 Monitoring	12 Pers. Toxic Subs
6	Aquatic Habitat	x							x									x	
8	Salmon and Trout								x									x	
9	Walleye and Hexagenia								x									x	
17	Preyfish Populations								x									x	
18	Sea Lamprey								x									x	
68	Native Unionid Mussels								x									x	
72	Fish Entrainment								x									x	
93	Lake Trout and Scud (Diaporeia hoyi)								x									x	
101	Deformities, Erosion, Lesions and Tumors in Nearshore Fish								x									x	x
104	Benthos Diversity and Abundance								x									x	
109	Phytoplankton Populations								x									x	
111	Phosphorus Concentrations and Loadings	x						x	x	x								x	
113	Contaminants in Recreational Fish							x	x									x	x
114	Contaminants In Young-of-the-Year Spottail Shiners							x										x	x
115	Contaminants in Colonial Nesting Waterbirds							x	x									x	x
116	Zooplankton Populations								x									x	
117	Atmospheric Deposition of Toxic Chemicals																	x	x
118	Toxic Chemical Concentrations in Offshore Waters							x										x	x
119	Concentrations of Contaminants in Sediments Cores																	x	x
120	Contaminant Exchange Between Air to Water & Water to Sediment							x										x	x
3509	Capacities of Sustainable Landscape Partnerships					x													
3510	Organizational Richness of Sustainable Landscape Partnerships					x													
3511	Integration of ecosystem management principles across landscapes					x													
3512	Integration of Sustainability Principles Across Landscapes					x													
3513	Citizen/Community Place-Based Stewardship Activities					x													
4081	Fecal Pollution Levels of Nearshore Recreational Waters				x			x	x									x	
4083	Chemical Contaminants in Fish Tissue				x			x	x									x	x
4088	Chemical Contaminant Intake from Air, Water, Soil and Food				x													x	x
4175	Drinking Water Quality				x			x	x									x	x
4176	Air Quality				x			x										x	
4177	Chemical Contaminants in Human Tissue				x			x										x	x
4178	Radionuclides				x			x										x	
4179	Geographic Patterns and Trends in Disease Incidence				x														
4501	Coastal Wetland Invertebrate Community Health	x							x									x	
4502	Coastal Wetland Fish Community Health	x							x									x	
4503	Deformities/Eroded Fins/Lesions/Tumors (DELT) in Fish	x							x									x	x
4504	Amphibian Diversity and Abundance	x																x	
4506	Contaminants in Snapping Turtle Eggs	x						x	x									x	x
4507	Wetland-dependent Bird Diversity and Abundance	x							x									x	
4510	Coastal Wetland Area by Type	x							x									x	
4511	Gain in Restored Coastal Wetland Area by Type	x							x									x	
4513	Presence, Abundance & Expansion of Invasive Plants	x	x						x									x	
4516	Sediment Flowing Into Coastal Wetlands	x						x	x									x	
4519	Global Warming: Number of Extreme Storms	x	x				x												
4857	Global Warming: 1st Emergence of Water Lilies in Coastal Wetlands	x					x												
4858	Global Warming: Ice Duration on the Great Lakes	x					x												
4860	Nitrates and Total Phosphorus Into Coastal Wetlands	x								x								x	
4861	Water Level Fluctuations	x																x	
7000	Urban Density			x														x	
7002	Land Conversion			x														x	
7006	Brownfield Redevelopment			x															
7012	Mass Transportation			x															
7028	Sustainable Agricultural Practices			x														x	
7042	Aesthetics			x		x			x									x	
7043	Economic Prosperity					x													
7053	Green Planning Process			x															
7055	Habitat Adjacent to Coastal Wetlands	x		x														x	
7056	Water Consumption					x													
7057	Energy Consumption					x													
7059	Wastewater Pollutant Loading							x										x	x
7060	Solid Waste Generation					x													
8114	Habitat Fragmentation																		
8129	Area, Quality, and Protection of Special Lakeshore Communities		x						x									x	
8131	Extent of Hardened Shoreline		x	x					x									x	
8132	Nearshore Land Use Intensity		x	x					x									x	
8134	Nearshore Plant and Wildlife Problem Species		x						x									x	
8135	Contaminants Affecting Productivity of Bald Eagles		x						x									x	x
8136	Extent and Quality of Nearshore Natural Land Cover		x						x									x	
8137	Nearshore Species Diversity and Stability		x						x									x	
8139	Community / Species Plans		x			x												x	
8140	Financial Resources Allocated to Great Lakes Programs		x			x													
8141	Shoreline Managed Under Integrated Management Plans		x	x		x													
8142	Streamflow	x	x					x	x	x								x	x
8146	Artificial Coastal Structures		x						x									x	
8147	Contaminants Affecting the American Otter	x	x					x	x									x	x
8149	Nearshore Protected Areas		x																
8150	Breeding Bird Diversity and Abundance						x		x									x	
8161	Threatened Species	x	x															x	
9000	Acid Rain						x	x										x	x
9001	Atmospheric Visibility: Prevention of Significant Deterioration						x											x	
80	COUNT	21	17	11	8	13	6	18	39	3	0	0	0	0	0	0	0	60	19

ID#	Indicator name	GLWQA Annex (con'd)					IJC Desired Outcomes									GLFC Obj.			
		13 Non-point Sources	14 Contam. Sed's	15 Atmos. Dep.	16 Groundwater	17 Res. & Devel.	1 Fishability	2 Swimmability	3 Drinkability	4 Healthy Humans	5 Economic Viability	6 Bio. Integ. & Divers.	7 Virt. Elim. PTS	8 Excess Phos.	9 Physical Env. Integ	Ontario	Erie	Huron	Michigan
6	Aquatic Habitat											x			x	x	x	x	x
8	Salmon and Trout											x				x		x	x
9	Walleye and Hexagenia											x				x	x	x	
17	Preyfish Populations											x				x	x	x	x
18	Sea Lamprey											x				x	x	x	x
68	Native Unionid Mussels											x							
72	Fish Entrainment																		
93	Lake Trout and Scud (Diaporeia hoyi)											x				x	x	x	x
101	Deformities, Erosion, Lesions and Tumors in Nearshore Fish												x						
104	Benthos Diversity and Abundance											x							
109	Phytoplankton Populations											x		x					
111	Phosphorus Concentrations and Loadings	x										x		x			x		
113	Contaminants in Recreational Fish						x			x		x	x			x	x	x	x
114	Contaminants In Young-of-the-Year Spottail Shiners											x	x						
115	Contaminants in Colonial Nesting Waterbirds											x	x				x		
116	Zooplankton Populations																		
117	Atmospheric Deposition of Toxic Chemicals			x		x							x						
118	Toxic Chemical Concentrations in Offshore Waters												x						
119	Concentrations of Contaminants in Sediments Cores		x										x						
120	Contaminant Exchange Between Air to Water & Water to Sediment			x		x							x						
3509	Capacities of Sustainable Landscape Partnerships																		
3510	Organizational Richness of Sustainable Landscape Partnerships																		
3511	Integration of ecosystem management principles across landscapes																		
3512	Integration of Sustainability Principles Across Landscapes																		
3513	Citizen/Community Place-Based Stewardship Activities																		
4081	Fecal Pollution Levels of Nearshore Recreational Waters							x		x									
4083	Chemical Contaminants in Fish Tissue						x			x			x			x	x	x	x
4088	Chemical Contaminant Intake from Air, Water, Soil and Food					x				x									
4175	Drinking Water Quality				x				x	x					x				
4176	Air Quality	x								x									
4177	Chemical Contaminants in Human Tissue					x				x			x						
4178	Radionuclides					x				x									
4179	Geographic Patterns and Trends in Disease Incidence					x				x									
4501	Coastal Wetland Invertebrate Community Health	x										x			x				
4502	Coastal Wetland Fish Community Health	x										x			x				
4503	Deformities/Eroded Fins/Lesions/Tumors (DELT) in Fish					x							x						
4504	Amphibian Diversity and Abundance	x										x			x				
4506	Contaminants in Snapping Turtle Eggs												x						
4507	Wetland-dependent Bird Diversity and Abundance	x										x			x				
4510	Coastal Wetland Area by Type	x													x				
4511	Gain in Restored Coastal Wetland Area by Type	x													x				
4513	Presence, Abundance & Expansion of Invasive Plants	x										x							
4516	Sediment Flowing Into Coastal Wetlands	x													x				
4519	Global Warming: Number of Extreme Storms														x				
4857	Global Warming: 1st Emergence of Water Lilies in Coastal Wetlands																		
4858	Global Warming: Ice Duration on the Great Lakes														x				
4860	Nitrates and Total Phosphorus Into Coastal Wetlands													x					
4861	Water Level Fluctuations					x									x				
7000	Urban Density	x													x				
7002	Land Conversion	x													x				
7006	Brownfield Redevelopment														x				
7012	Mass Transportation																		
7028	Sustainable Agricultural Practices	x													x				
7042	Aesthetics																		
7043	Economic Prosperity										x								
7053	Green Planning Process																		
7055	Habitat Adjacent to Coastal Wetlands	x													x				
7056	Water Consumption										x								
7057	Energy Consumption										x								
7059	Wastewater Pollutant Loading												x						
7060	Solid Waste Generation										x								
8114	Habitat Fragmentation																		
8129	Area, Quality, and Protection of Special Lakeshore Communities	x													x				
8131	Extent of Hardened Shoreline	x													x				
8132	Nearshore Land Use Intensity	x										x			x				
8134	Nearshore Plant and Wildlife Problem Species					x						x							
8135	Contaminants Affecting Productivity of Bald Eagles					x						x	x						
8136	Extent and Quality of Nearshore Natural Land Cover	x										x			x				
8137	Nearshore Species Diversity and Stability											x							
8139	Community / Species Plans	x																	
8140	Financial Resources Allocated to Great Lakes Programs																		
8141	Shoreline Managed Under Integrated Management Plans																		
8142	Streamflow	x				x									x				
8146	Artificial Coastal Structures														x				
8147	Contaminants Affecting the American Otter					x						x	x						
8149	Nearshore Protected Areas														x				
8150	Breeding Bird Diversity and Abundance											x							
8161	Threatened Species					x						x			x				
9000	Acid Rain			x		x									x				
9001	Atmospheric Visibility: Prevention of Significant Deterioration			x															
80	COUNT	20	1	4	1	14	2	1	1	9	4	26	15	3	26	8	9	8	7

ID#	Indicator name	GLFC Obj.	Beneficial Use Impairments														Totals
		Superior	1 F&W Consumption	2 Tainting	3 F&W Pop's	4 Tumors	5 Deformities/Reprod	6 Benthos	7 Dredging	8 Eutrophication	9 Drinking Water	10 Beach Closings	11 Aesthetics	12 Ag./ Indust. Costs	13 Phyto-/Zoo-plankton	14 F&W Habitat	
6	Aquatic Habitat	x														x	16
8	Salmon and Trout	x			x												16
9	Walleye and Hexagenia				x			x									16
17	Preyfish Populations	x			x												17
18	Sea Lamprey	x			x												14
68	Native Unionid Mussels							x									9
72	Fish Entrainment				x												8
93	Lake Trout and Scud (Diaporeia hoyi)	x			x			x									18
101	Deformities, Erosion, Lesions and Tumors in Nearshore Fish					x											10
104	Benthos Diversity and Abundance							x									11
109	Phytoplankton Populations														x		11
111	Phosphorus Concentrations and Loadings									x							15
113	Contaminants in Recreational Fish	x	x														19
114	Contaminants In Young-of-the-Year Spottail Shiners																9
115	Contaminants in Colonial Nesting Waterbirds				x		x										14
116	Zooplankton Populations														x		9
117	Atmospheric Deposition of Toxic Chemicals																10
118	Toxic Chemical Concentrations in Offshore Waters																8
119	Concentrations of Contaminants in Sediments Cores																8
120	Contaminant Exchange Between Air to Water & Water to Sediment																12
3509	Capacities of Sustainable Landscape Partnerships																4
3510	Organizational Richness of Sustainable Landscape Partnerships																4
3511	Integration of ecosystem management principles across landscapes																4
3512	Integration of Sustainability Principles Across Landscapes																4
3513	Citizen/Community Place-Based Stewardship Activities																4
4081	Fecal Pollution Levels of Nearshore Recreational Waters											x					12
4083	Chemical Contaminants in Fish Tissue	x	x														19
4088	Chemical Contaminant Intake from Air, Water, Soil and Food																8
4175	Drinking Water Quality										x						15
4176	Air Quality																8
4177	Chemical Contaminants in Human Tissue																10
4178	Radionuclides																9
4179	Geographic Patterns and Trends in Disease Incidence																5
4501	Coastal Wetland Invertebrate Community Health				x												10
4502	Coastal Wetland Fish Community Health				x												10
4503	Deformities/Eroded Fins/Lesions/Tumors (DELT) in Fish						x										10
4504	Amphibian Diversity and Abundance				x												9
4506	Contaminants in Snapping Turtle Eggs																9
4507	Wetland-dependent Bird Diversity and Abundance				x												10
4510	Coastal Wetland Area by Type															x	9
4511	Gain in Restored Coastal Wetland Area by Type															x	9
4513	Presence, Abundance & Expansion of Invasive Plants															x	10
4516	Sediment Flowing Into Coastal Wetlands															x	12
4519	Global Warming: Number of Extreme Storms																6
4857	Global Warming: 1st Emergence of Water Lilies in Coastal Wetlands																5
4858	Global Warming: Ice Duration on the Great Lakes																6
4860	Nitrates and Total Phosphorus Into Coastal Wetlands									x							8
4861	Water Level Fluctuations															x	9
7000	Urban Density																6
7002	Land Conversion																6
7006	Brownfield Redevelopment																4
7012	Mass Transportation																3
7028	Sustainable Agricultural Practices																6
7042	Aesthetics												x				7
7043	Economic Prosperity																3
7053	Green Planning Process																2
7055	Habitat Adjacent to Coastal Wetlands																11
7056	Water Consumption																5
7057	Energy Consumption																5
7059	Wastewater Pollutant Loading																8
7060	Solid Waste Generation																5
8114	Habitat Fragmentation																3
8129	Area, Quality, and Protection of Special Lakeshore Communities															x	9
8131	Extent of Hardened Shoreline															x	10
8132	Nearshore Land Use Intensity															x	11
8134	Nearshore Plant and Wildlife Problem Species				x												10
8135	Contaminants Affecting Productivity of Bald Eagles				x		x										14
8136	Extent and Quality of Nearshore Natural Land Cover															x	10
8137	Nearshore Species Diversity and Stability				x												9
8139	Community / Species Plans																7
8140	Financial Resources Allocated to Great Lakes Programs																5
8141	Shoreline Managed Under Integrated Management Plans																7
8142	Streamflow									x						x	17
8146	Artificial Coastal Structures															x	8
8147	Contaminants Affecting the American Otter				x		x										14
8149	Nearshore Protected Areas																5
8150	Breeding Bird Diversity and Abundance				x												7
8161	Threatened Species				x											x	15
9000	Acid Rain																10
9001	Atmospheric Visibility: Prevention of Significant Deterioration																5
80	COUNT	7	2	0	17	1	4	4	0	3	1	1	1	0	2	13	

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