Handbook of Ecological Indicators for Assessment of Ecosystem Health

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CHAPTER 4

Development and Application of Ecosystem Health Indicators in the North American Great Lakes Basin

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Assessing the health of the North American Great Lakes Basin ecosystem is a significant challenge. The lakes themselves contain one-fifth of the world's fresh surface water with over 17,000 km of shoreline. The basin consists of over 520,000 km^2 of land with about 33.5 million people living there. The basin (including the St. Lawrence River) is governed by two nations, eight states, two provinces, and hundreds of municipal and local governments. A set of Great Lakes Basin ecosystem health indicators will enable the Great Lakes community to work together within a consistent framework to assess and monitor changes in the state of the ecosystem. Data collected through various government and nongovernment programs can be analyzed, interpreted, and ecosystem health information characterized within a series of such indicators. A consensus agreement by environmental management agencies and other interested stakeholders about what information is necessary and sufficient to characterize the state of the Great Lakes ecosystem's health, and to measure progress toward ecosystem goals, will facilitate more efficient monitoring and

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reporting programs. This chapter will present the process for indicator selection or development, with some examples of indicator reporting.

4.1 INTRODUCTION

4.1.1 Background on the Great Lakes Basin

The purpose of this chapter is to present information on some of the indicators representing various ecosystem components of the Great Lakes Basin.

Assessing the health of the Great Lakes Basin ecosystem is a significant challenge. The Great Lakes St. Lawrence River Basin consists of over 520,000 km^2 of land, and the lakes themselves contain one-fifth of the world's fresh surface water surrounded by over 17,000 km of shoreline. About 33.5 million people reside within the basin. Natural resources within the basin supply tens of millions of people with drinking water, support a multibillion dollar recreation and tourism industry, provide habitat for thousands of plant and animal species, offer transportation and manufacturing opportunities, and support an extensive agricultural industry.

Governance in the basin is complex. Political jurisdictions include two nations, eight states, two provinces, dozens of tribes and First Nations, and hundreds of municipal and local governments. Within each of the governance structures are multiple agencies, offices, and other organizations that exercise jurisdiction over one or more Great Lakes Basin ecosystem components.

The U.S. and Canada have collectively spent billions of dollars and uncounted hours attempting to reverse the effects of cultural eutrophication, toxic chemical pollution, overfishing, habitat destruction, introduced species, and other human-induced pressures on the Great Lakes. To assess if past programs have been successful and if future or continuing programs will result in environmental improvement commensurate with the resources expended, a consensus agreement is desired by environmental management agencies and other interested stakeholders about what information is necessary and sufficient to characterize the state of Great Lakes Basin ecosystem. Having agreed on information requirements, the relative strengths of the various agencies and organizations can then be utilized to improve the timeliness and quality of the data collection and the availability of the information to multiple users.

The ecosystem approach is the defining mechanism by which management agencies are meant to carry out their research and deliver their regulatory programs (United States and Canada, 1987; Vallentyne and Beeton, 1988; Hartig and Vallentyne, 1989; Hartig and Zarull, 1992; International Joint Commission, 1995). In real terms, the ecosystem approach has come to mean a comprehensive approach to environmental issues, considering the interacting living (including humans) and nonliving components of the Great Lakes Basin.

The Great Lakes Water Quality Agreement (GLWQA) between the U.S. and Canada was signed in 1972 by Prime Minister Pierre Trudeau and President Richard Nixon in order "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem" (United States and Canada, 1987). Its primary intent was to decrease external loadings of phosphorus to the lakes. The agreement was revised in 1978, to establish (among other things) annual loading targets of phosphorus for each of the Great Lakes. In 1987 the agreement was amended, placing much more emphasis on control and elimination of toxic contaminants and on a broad ecosystem approach to solving the Great Lakes ecosystem problems.

The 1987 revisions to the agreement also introduced some far-reaching concepts that have had significant impact on management planning and implementation for the Great Lakes. For instance, ecosystem objectives are to be developed for each of the Great Lakes, and indicators are to be identified to measure progress towards those objectives. The governments of Canada and the U.S. also agreed to report on progress toward the agreement goals and objectives every two years.

The State of the Lakes Ecosystem Conference (SOLEC) was established by the governments of Canada and the United States in 1992 in response to reporting requirements of the GLWQA. It is held every two years, and is designed to report on the condition of the Great Lakes Basin ecosystem regarding progress toward the goals and objectives of the Great Lakes Water Quality Agreement. The conferences are science-based rather than programmatic, and they are a result of consultation and collaboration between U.S. and Canada, and between federal, state, provincial and local government agencies, environmental groups, industry and the public.

No one organization has the resources or the mandate to examine the state of all the Great Lakes ecosystem components, but dozens of organizations and thousands of individuals routinely collect data, analyze them, and report on parts of the ecosystem. Through the SOLEC process, however, data and other information are collected from multiple sources and are reported as a series of indicators on Great Lakes ecosystem components.

4.1.2 Indicator Selection

An indicator is 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 (Canada and the United States, 1999). Used alone or in combination, indicators provide the means to assess progress towards one or more objectives: are conditions improving so that the objective is closer to being met, or are conditions deteriorating? The achievement of these objectives then leads towards the achievement of higher order goals and a vision for the ecosystem.

Application of the indicators requires two pieces of information: the measurement and some sort of reference value. The measurement describes the observed state of the ecosystem component. The reference value, or end point, reflects the desired state of the ecosystem component. Qualitative assessments are derived by comparing the observed measurements to the desired states.

With respect to the health of the Great Lakes, scientists and nonscientists have engaged in the development of appropriate ecosystem indicators (Ryder and Edwards, 1985; Edwards and Ryder, 1990; Bertram and Reynoldson, 1992; Bertram et al., 2002). There is a continuum of proposed indicators from the ones that are easily understood by the nonscientific public, to those that are more technical and better understood by the scientific community.

The selection of the Great Lakes indicators through the SOLEC process was based on a few key principles (Bertram et al., 2002), outlined below:

- *Build upon the work of others.* Over 800 existing or proposed indicators of the condition of Great Lakes ecosystem components were identified. From this large pool of indicators, a subset was selected and then further refined, combined or modified to best represent the ecosystem component under consideration.
- *Focus on broad spatial scales.* SOLEC assessments are oriented toward the whole Great Lakes watershed and at the individual lake basins. Other venues are available for reporting on more local conditions, such as specific harbors or wetlands.
- *Select a framework for subdividing the Great Lakes Basin ecosystem.* A combination of geographic areas and nongeographic issues provided an organizing framework. They included offshore and nearshore waters, coastal wetlands, nearshore terrestrial areas, human health, land use, and societal indicators.
- *Select a system for types of indicators.* There are several classification schemes or models for indicators, one of which is the state–pressure–response (human activities) model (OECD, 1993; Bertram and Stadler-Salt, 1999). Indicators were selected to assess the state of the ecosystem components and the pressures or "stressors" that affect the state. Some human activities that affect or result from the stressors were included, but the initial focus of the indicators was on the state and stressor indicators.
- *Identify criteria for indicator selection.* The primary criteria were for each indicator to be necessary — that is, contributes a unique perspective of an ecosystem component; and feasible — that is, practical and able to be implemented. Also, the entire suite of indicators should be sufficient to provide a comprehensive assessment of Great Lakes ecosystem health.

The process for identifying the current Great Lakes indicators required about two years and involved at least 150 people, and the process is continuing. A core working group and an expert panel were created for each of the geographic areas and nongeographic issues under consideration. Both U.S. and Canadian expertise was involved. Each of the working groups mined indicators and indicator ideas from existing sources. The groups then screened their long list and revised, combined or created new indicators as needed.

The work of all the groups was combined into the proposed Great Lakes indicator list and presented at SOLEC 1998. Within the framework categories, indicators for nearshore and open waters, coastal wetlands and nearshore terrestrial environments were all well represented. The human health category has fewer indicators, in part because of the difficulty of identifying human health effects due to the Great Lakes influence. More reliance was therefore placed on indicators of potential human health exposure.

The organization of the list of Great Lakes indicators is flexible and can be easily regrouped. For example, the indicators can be grouped according to environmental compartment (e.g., air, water, land, sediments, biota, humans) or by Great Lakes issues (e.g., contaminants and pathogens, nutrients, non-native species, habitat, climate change, stewardship).

4.1.3 Definition of the Selected Indicators

The working groups applied the three criteria of "necessary," "sufficient," and "feasible," to over 800 potential indicators. Through scientific review and the application of secondary criteria, this number was reduced to 80 in 1998. This list of indicators continues to evolve. Some indicators may be revised, some indicators may get added over time, and some indicators may be removed from the list. This will help the Great Lakes community to ensure that it can respond to new or emerging issues. For example, indicators for groundwater, forests, societal response, agriculture, and others were not included in the original set, but they were proposed and some were developed in conjunction with SOLEC 2002.

For SOLEC 2002, reports were prepared on 43 of the current 82 (reconfigured from the 80 presented in 1998) Great Lakes indicators plus 10 example reports for additional proposed indicators. The 43 indicators were selected and reported on because data were readily available. At the conference, the indicators were discussed in workshop sessions, and comments, criticisms, and suggestions for improvements were noted.

Data for a few of the 43 reported indicators were not available basin-wide. In other cases only some of the data for the indicators were presented. The remaining indicators have yet to be reported because the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs may be necessary. Additionally, some indicators are still in the development stage. Over time, monitoring and reporting on the full suite of indicators is expected to be implemented.

After the necessary refinements were made to some of the indicator reports, they were organized according to the pressure–state–human response model, summarized, and compiled into a formal report, "State of the Great Lakes 2003" (Canada and the U.S., 2003a). The complete indicator reports as prepared by the expert authors, including literature citations and references to data sources, were similarly compiled into a companion report, "Implementing Indicators 2003 — A Technical Report" (Canada and the U.S., 2003b).

4.2 GENERAL CONSIDERATIONS

4.2.1 Ecological Description of the Great Lakes Basin

The Laurentian Great Lakes are large and complex. The basin's ecology and human land use are driven by two main factors: the geography of the basin, and its geology. The lakes differ in their ecology largely due to the vast geographic area that they occupy. From north to south, the Great Lakes Basin spans almost 11 degrees of latitude. This accounts for a significant climatic variation. In the north, the climate is characterized by short, warm summers and long, cold winters. In the south, the summers are longer and warmer, the winters somewhat shorter and milder. The geology of the basin has also influenced its ecology, and has determined human land uses. The south is dominated by agriculture because of its deep fertile soils, as well as the more favorable climate. The north is generally forested with minimal agriculture because of the thin soils overlaying granite rock, and also because of the cooler climate. Large urban areas are generally confined to the southern part of the basin, with a couple of exceptions in the Lake Superior Basin.

As a result of this land use and human settlement pattern, one can characterize the issues in the basin as follows.

4.2.1.1 Toxic Contaminants

Contaminants in the Great Lakes have shown a significant decrease over the last 20 to 25 years as a result of actions taken by Canada and the U.S. to ban and control contaminants such as mercury, DDT and PCBs from entering the Great Lakes. Contaminants are still an issue in localized areas such as harbors and embayments, and fish consumption advisories exist in many areas of the Great Lakes.

4.2.1.2 Land Use

Major population centers in the Great Lakes Basin include the northwestern part of the Canadian shoreline of Lake Ontario, the south shore of Lake Erie, most of the southern Lake Michigan Basin, and two centers in Lake Superior (Duluth-Superior and Thunder Bay). The St. Clair–Detroit River ecosystem is one of the most highly industrialized areas in the Great Lakes Basin. The major cities of Port Huron and Detroit, Michigan, and Sarnia and Windsor, Ontario, are major petrochemical and manufacturing centers. Lake Huron has the lowest human population density in the entire basin, and as such, has shown fewer environmental problems.

The Lake Erie Basin includes a Carolinian Zone that has been described as Canada's most endangered major ecosystem. The Carolinian Zone sustains at least 18 globally rare vegetation community types; 36 globally rare species; and 108 vulnerable, threatened, and endangered species. The watershed also has habitats that sustain 143 fish species, many of which contribute to a thriving sport and commercial fishery.

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

4.2.1.3 Invasive Species

There are over 150 species of invasive non-native species in the Great Lakes Basin. Many of these species are aquatic. The impact of non-native species on Great Lakes ecology and economy has been documented for several species, including the sea lamprey and zebra mussel. Today, for example, as a result of zebra mussel infestation in Lake Erie, the entire ecology of the Lake has changed, and phenomena such as type E botulism deaths in fish and wildlife have appeared, and may be linked to zebra mussels. Millions of dollars per year are spent keeping zebra mussels from clogging water intake pipes. Invasive non-native species continue to be a concern for Lake Michigan. In 2002, the non-native fish species, the ruffe, was found in Lake Michigan for the first time. Other non-native species, including zebra mussels and round goby, are continuing to impact Lake Michigan's aquatic ecosystems.

4.2.1.4 Habitat Status Including Wetlands

Much of the Lake Ontario watershed, tributaries, and nearshore lands remain degraded, particularly in the western basin, and new concerns continue to emerge to further complicate recovery efforts.

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

Lake Huron has over 30,000 islands, contributing to its distinction of having the longest shoreline of any lake in the world. The islands and nearshore areas still support a high diversity of aquatic and riparian species.

Aquatic habitats in the main basin of Lake Huron are in relatively good health. Many of the tributaries in the system, however, are still severely stressed by both development and point and nonpoint source pollution. These stressors are resulting in changes to tributary fish community composition.

4.2.1.5 Lake Ecology

Populations of fish-eating waterbirds in Lake Ontario have recovered and are reproducing normally. Recent data have shown that several other key indicator species such as the bald eagle (within the Lake Ontario basin), otter, and mink are also making a comeback.

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

The health of fish communities is of particular concern in the Great Lakes Basin because of their economic, recreational, and ecological importance. Current stressors to fish communities include continued habitat degradation, loss of food sources due to non-native species, and contamination. The fish community in Lake Superior is considered the healthiest, with the largest self-sustaining lake trout population in the entire system. In Lakes Michigan, Huron and Ontario, the top predator fish community is artificially maintained through hatchery rearing and stocking programs. In the last few years, however, natural reproduction of native lake trout has once again been documented at several locations in Lakes Huron and Ontario.

4.2.1.6 Nutrients

Although significant reductions in nutrient loadings have been achieved, phosphorus concentrations in Lake Erie appear to be increasing again and may be linked to a zone of oxygen depletion in the Central basin. Nutrients may be becoming an issue again in nearshore waters of Lake Ontario, leading to nuisance growths of *Cladophora.*

4.2.2 Data Collection Methods

No single organization has the resources or the mandate to examine the state of all the ecosystem components. Dozens of organizations collect data, analyze them, and report on parts of the ecosystem. A consensus by environmental management agencies and other interested stakeholders about what information is necessary and sufficient to characterize the state of Great Lakes ecosystem health will facilitate more efficient monitoring and reporting.

The SOLEC approach is to use the relative strengths of the agencies to improve the timeliness and quality of the data collection and the availability of the information to multiple users. Subject matter experts are invited to contribute their information about a particular indicator and to make assessments of the relative state of the ecosystem component or pressure being addressed. Quality assurance and quality control programs are implemented by each organization that collects the data. For SOLEC reporting, "Implementing Indicators 2003 — A Technical Report" (Canada and the U.S., 2003b) offers references to data sources to facilitate the tracing of data and exploration of methodologies.

4.3 RESULTS

For SOLEC 2002 and for the State of the Great Lakes 2003 reports (Canada and the U.S., 2003a, 2003b), the indicators were grouped into the categories of state, pressure, and response. Within the state and pressure categories, the indicators were further divided into those with data that were basin-wide and consistent over time (at least within a lake basin) and those whose data represented smaller geographic areas or which were not consistent between areas or over time. There were no response indicators that were consistent over the entire Great Lakes Basin. The following example indicator findings are grouped accordingly.

4.3.1 State Indicators — Complete

4.3.1.1 Hexagenia

The distribution, abundance, biomass, and annual production of the burrowing mayfly *Hexagenia* in mesotrophic Great Lakes habitats are measured directly. These metrics are used as the indicator of ecosystem health because *Hexagenia* is intolerant of pollution, and is therefore a good reflection of water and lakebed sediment quality in mesotrophic Great Lakes habitats. *Hexagenia* was historically the dominant, large, benthic invertebrate in these habitats, and was an important item in the diets of many valuable fishes. Figure 4.1 shows the populations of *Hexagenia* in Western Lake Erie over the past 11 years, with a clear indication of a population recovery (Ciborowski et al., unpublished observations).

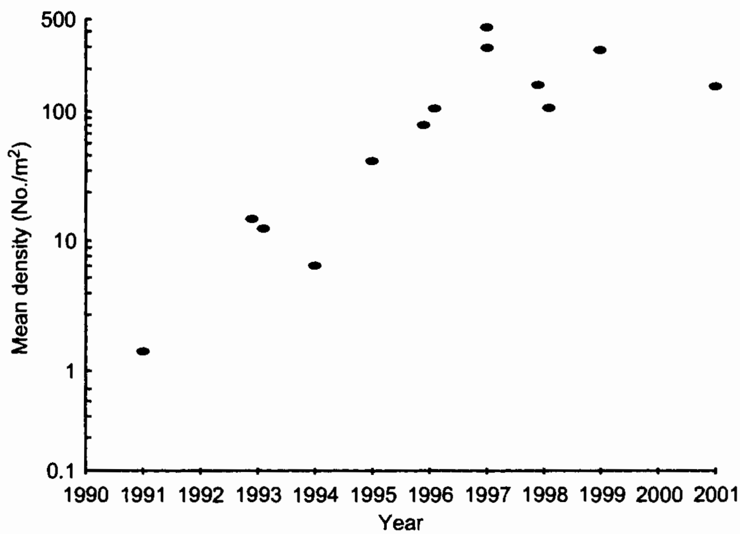

Figure 4.1 Density of *Hexagenia* in western Lake Erie (1991 to 2001). From Ciborowski, J., Krieger, K., Schloesser, D and Corkum, L, unpublished.

4.3.1.2 Wetland Dependent Bird Diversity and Abundance

Assessments of wetland-dependent bird diversity and abundance in the Great Lakes Basin are used to evaluate health and function of coastal and inland wetlands. Breeding birds are valuable components of Great Lakes wetlands and rely on physical, chemical and biological health of their habitats. Because these relationships are particularly strong during the breeding season, presence and abundance of breeding individuals can provide a source of information about wetland status and trends. When long-term monitoring data are combined with an analysis of habitat characteristics, trends in species abundance and diversity can contribute to an assessment of how well Great Lakes coastal wetlands are able to support birds and other wetland-dependent wildlife. Populations of several wetland-dependent birds are believed to be at risk due to continuing loss and degradation of their habitats. Figure 4.2 (Weeber and Vallianatos, 2000) shows results for four bird species.

While five years of data are not enough to draw any definitive conclusions, clearly the trends in these populations are declining or at best remaining static.

4.3.1.3 Area, Quality and Protection of Alvar Communities

This indicator assesses the status of alvars. Alvar communities are naturally open habitats occurring on flat limestone bedrock. Over 67% of known alvar occurrences within the Great Lakes Basin are close to the shoreline.

More than 90% of the original extent of alvar habitats has been destroyed or substantially degraded. Emphasis is focused on protecting the remaining 10%. Approximately 64% of the remaining alvar areas exist within Ontario,

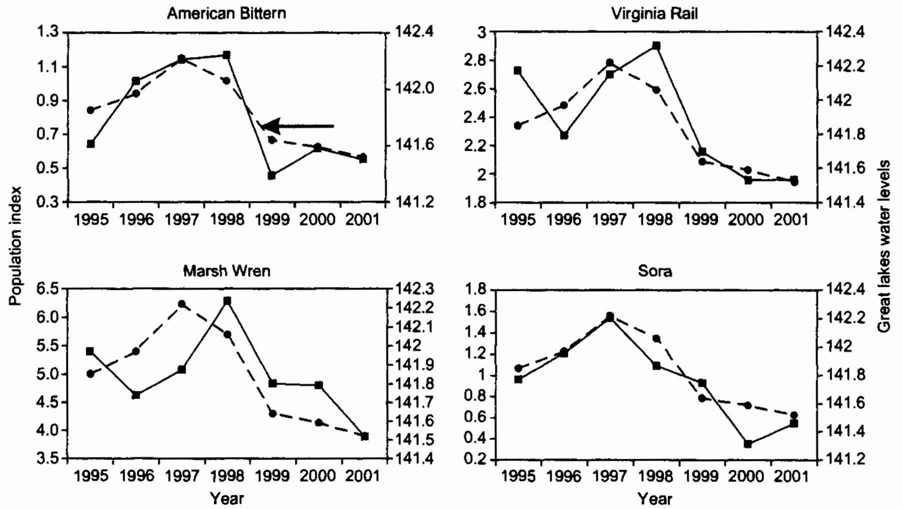

Figure 4.2 Population index trends for selected wetland dependent birds and water levels. From *Implementing Indicators 2003 — A Technical Report* (Canada and the U.S., 2003b).

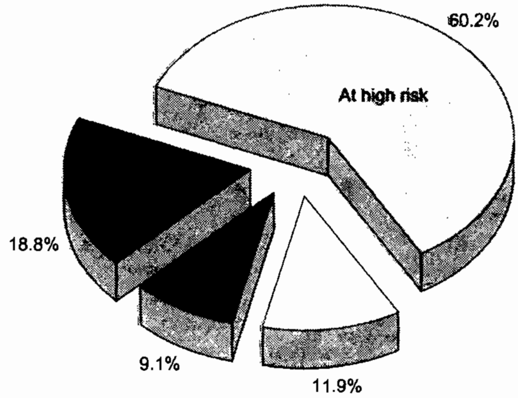

Figure 4.3 Protection status for Great Lakes alvars. From *Implementing Indicators 2003 — A Technical Report* (Canada and the U.S., 2003b).

16% in New York State, and 15% in Michigan and smaller areas in Ohio, Wisconsin and Quebec.

Less than 20% of the nearshore alvar acreage is currently fully protected, while over 60% is at high risk. Michigan has 66% of its nearshore alvar acreage in the "fully protected" category, while Ontario has only 7%. In part, this is a reflection of the much larger total shoreline acreage in Ontario (see Figure 4.3).

4.3.2 State Indicators — Incomplete

4.3.2.1 Native Freshwater Mussels

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

The introduction of the zebra mussel to the Great Lakes in the late 1980s has destroyed unionid communities throughout the system. Unionids were virtually extirpated from the offshore waters of western Lake Erie by 1990 and Lake St. Clair by 1994, with similar declines in the connecting channels and many nearshore habitats. There were on average 18 unionid species found in these areas before the zebra mussel invasion. After the invasion, 60% of surveyed sites had three or fewer native species left, 40% of sites had no native species left, and the abundance of native mussels had declined by 90 to 95% (see Figure 4.4).

Significant communities were, however, recently discovered in several nearshore areas where zebra mussel infestation rates are low. All of the refuge sites discovered to date have two things in common: they are very shallow (less

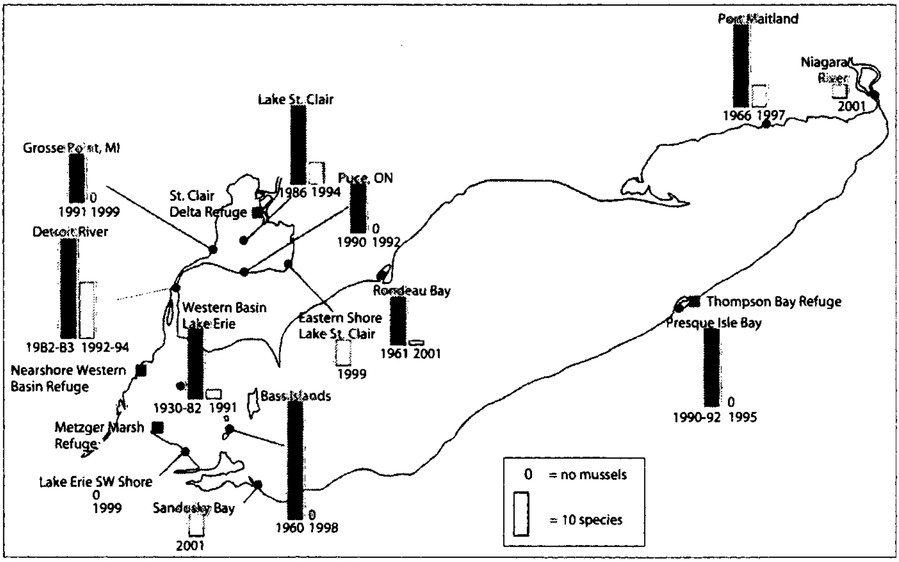

Figure 4.4 Abundance of native mussels in Lake Erie. From *Implementing Indicators 2003 — A Technical Report* (Canada and the U.S., 2003b).

than 1 to 2 m deep), and they have a high degree of connectivity to the lake that ensures access to host fishes. These features appear to combine with other factors to discourage the settlement and survival of zebra mussels.

4.3.3 Pressure Indicators — Complete

4.3.3.1 Phosphorus Concentrations and Loadings

This indicator assesses total phosphorus levels in the Great Lakes, and is used to support the evaluation of trophic status and food web dynamics in the Great Lakes. Efforts begun in the 1970s to reduce phosphorus loadings have been successful in maintaining or reducing nutrient concentrations in the lakes, although high concentrations still occur locally in some embayments and harbors. Phosphorus loads have decreased in part due to changes in agricultural practices (e.g., conservation tillage and integrated crop management), promotion of phosphorus-free detergents, and improvements made to sewage treatment plants and sewer systems. Figure 4.5 shows that the average concentrations in the open waters of Lakes Superior, Michigan, Huron, and Ontario are at or below expected levels (Environment Canada and USEPA, unpublished data). Concentrations in the three basins of Lake Erie fluctuate from year to year, and frequently exceed target concentrations. In Lakes Ontario and Huron, although most offshore waters meet the desired guideline, some offshore and nearshore areas and embayments experience elevated levels which could promote nuisance algae growths such as the attached green alga, *Cladophora*.

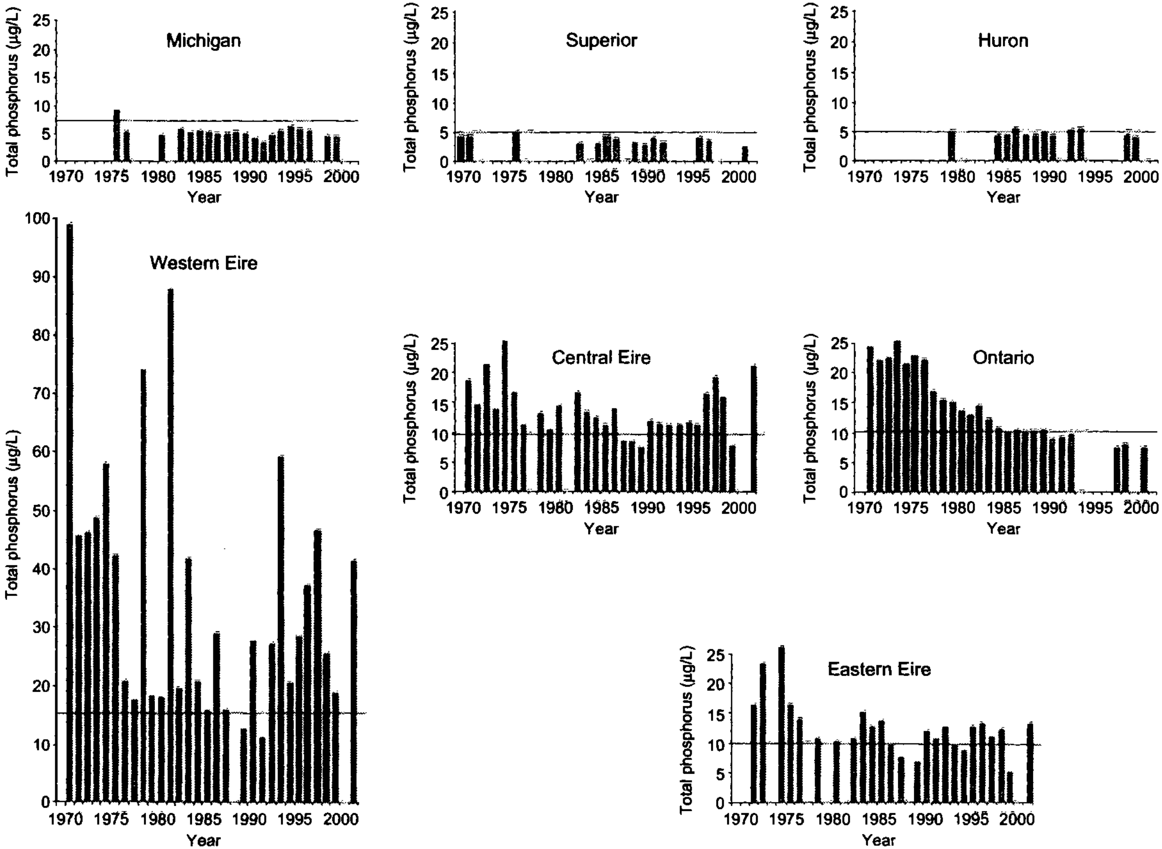

Figure 4.5 Total phosphorus concentration trends. From *Implementing Indicators 2003 — A Technical Report* (Canada and the U.S., 2003b).

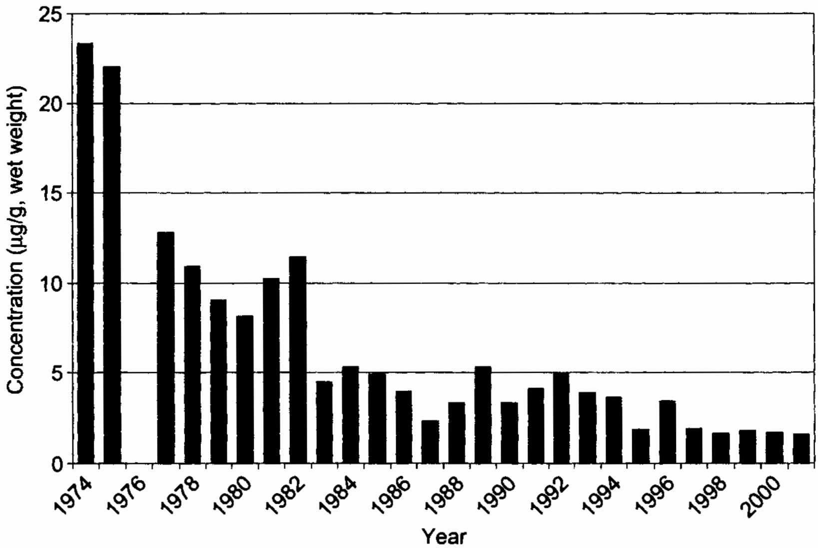

Figure 4.6 Concentration trends for DDE in herring gulls. From *Implementing Indicators 2003 — A Technical Report* (Canada and the U.S., 2003b).

4.3.3.2 Contaminants in Colonial Nesting Waterbirds

This indicator assesses current chemical concentration levels and trends as well as ecological and physiological endpoints in representative colonial waterbirds (gulls, terns, cormorants and herons). These features will be used to infer and measure the impact of contaminants on the health of colonial nesting waterbirds. An example of the kind of information provided by this indicator is shown in Figure 4.6 (Environment Canada, Canadian Wildlife Service, unpublished data). Levels of DDE in herring gull eggs are shown for a time series from 1974 to 2001.

4.3.3.3 Contaminants in Edible Fish Tissue

This indicator assesses the historical trends of the edibility of fish in the Great Lakes using fish contaminant data and a standardized fish advisory protocol. The approach is illustrated in Figure 4.7 where two of the Great Lakes are shown (USEPA, unpublished data). The various action levels for human consumption of fish are shown as horizontal lines with the corresponding action level noted. Unfortunately data gaps and data variability do not allow one to discern statistically significant trends at this time. Nevertheless, since the 1970s there have been declines in many persistent bioaccumulative toxic (PBT) chemicals in the Great Lakes Basin. However, these chemicals continue to be a significant concern regarding fish consumption.

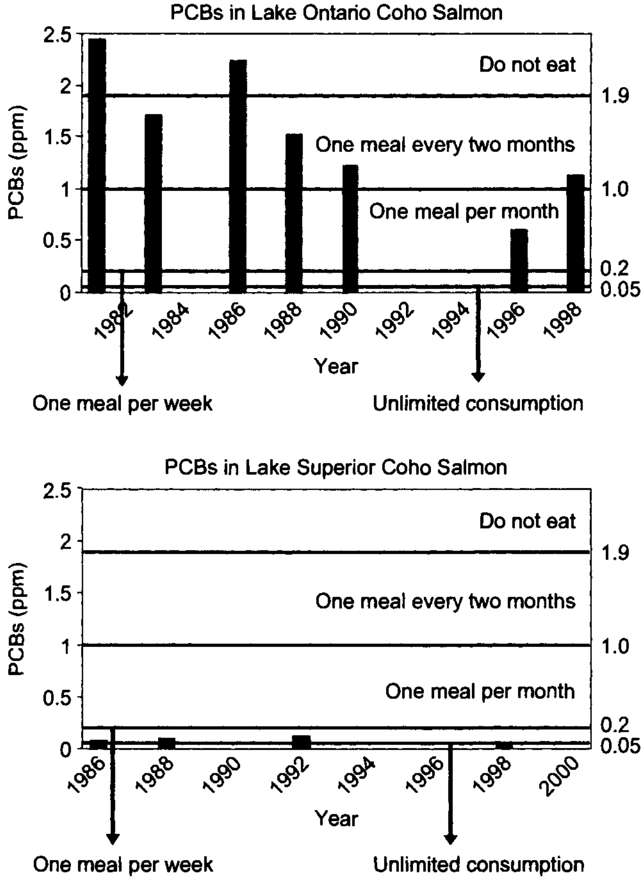

Figure 4.7 PCB Concentrations in edible portions of coho salmon in Lakes Ontario and Superior. From *Implementing Indicators 2003 — A Technical Report* (Canada and the U.S., 2003b).

4.3.4 Pressure Indicators – Incomplete

4.3.4.1 Mass Transportation

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

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

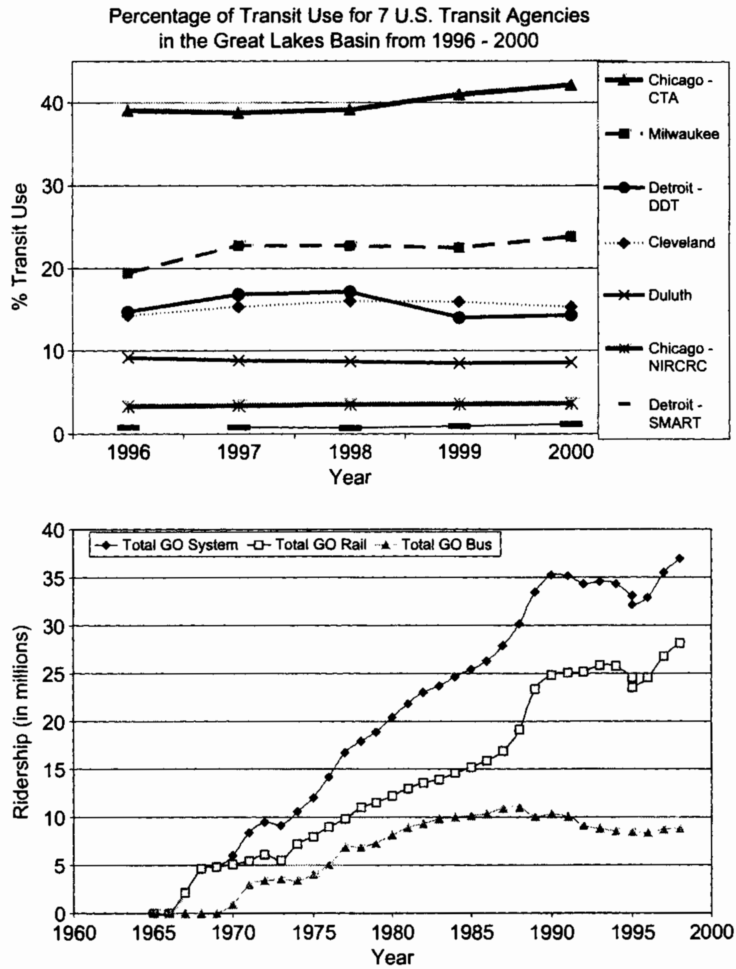

Figure 4.8 U.S. and Canadian public transit use trends. From *Implementing Indicators 2003 — A Technical Report* (Canada and the U.S., 2003b).

use. Percentage of transit use is high where the concentration of people is also the highest.

On the Canadian side, transit ridership is shown for the Greater Toronto Area (GTA) from 1965 to 2000. During that period there was a seven-fold increase in ridership, reflecting increased usage of the system, but also a major increase in population in the GTA (Figure 4.8).

4.3.4.2 *Escherichia Coli and Fecal Coliform Levels in Nearshore Recreational Waters*

This indicator assesses *E. coli* and fecal coliform levels in nearshore recreational waters. These levels act as a surrogate indicator for other

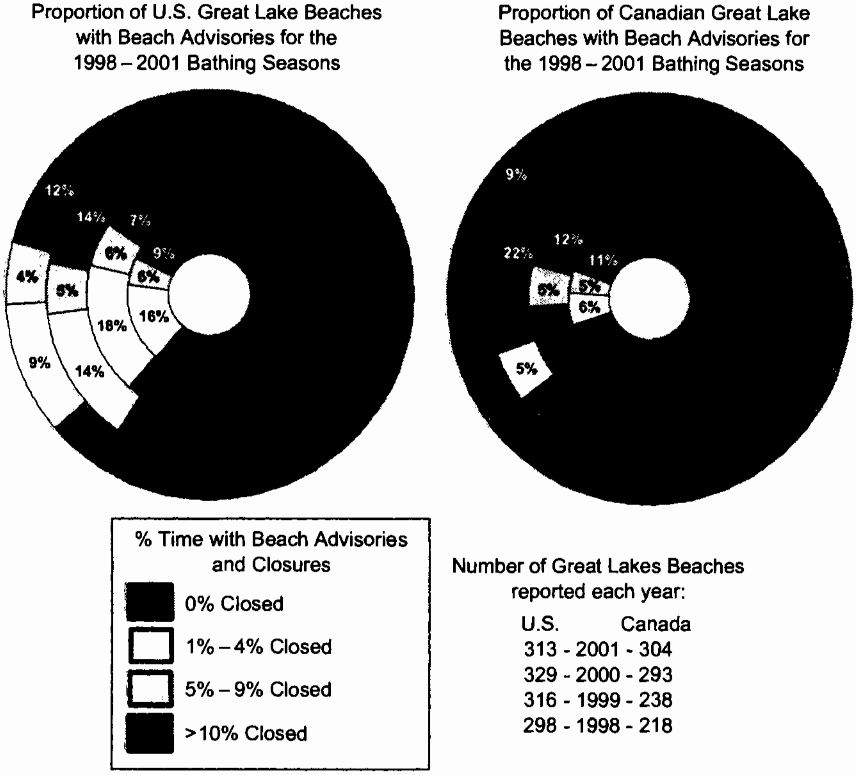

Figure 4.9 U.S. and Canadian beach closures 1998 to 2001. From *Implementing Indicators 2003 — A Technical Report* (Canada and the U.S., 2003b).

pathogen types, in order to infer potential harm to human health through body contact with nearshore recreational waters.

For both the U.S. and Canada, as the frequency of monitoring and reporting increases, more advisories (beach postings) and closings are also observed. Both countries experienced a doubling of beaches that had advisories or closings for more than 10% of the season in 2000. Further analysis of the data may show seasonal and local trends in recreational waters. If episodes of poor recreational water quality can be associated with specific events, then forecasting for episodes of poor water quality may become more accurate. In the Great Lakes Basin, bacteria levels tend to be predictable after storm events (Figure 4.9).

4.3.5 Response Indicators — Incomplete

4.3.5.1 Citizen/Community Place-Based Stewardship Activities

This indicator assesses the number, vitality and effectiveness of citizen and community stewardship activities. Community activities that focus on local

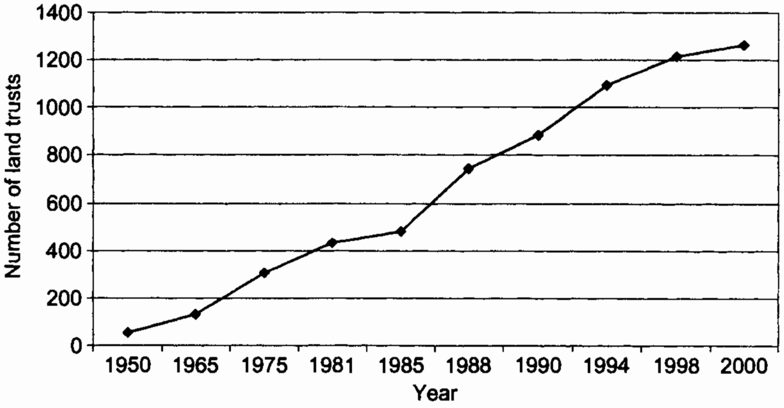

Figure 4.10 Trends in U.S. land trusts. From *Implementing Indicators 2003 — A Technical Report* (Canada and the U.S., 2003b).

landscapes or ecosystems provide a fertile context for the growth of the stewardship ethic and the establishment of a "sense of place."

Land trusts and conservancies are a particularly relevant subset of all community-based groups that engage in activities to promote sustainability within the Great Lakes Basin because of their direct focus on land and habitat protection. Data from the Land Trust Alliance's (LTA's) national land trust census show that the number of land trusts operating at least partly within the Great Lakes Basin increased from 3 in 1930 to 116 in 2000, with half of the increase occurring since 1990. The total area protected by land trusts in the Basin more than doubled between 1990 and 2000, rising from 177,077 to 397,784 acres. Nationally, protected land increased from 1,908,547 acres to 6,479,672 acres, according to LTA. The Nature Conservancy alone had protected an additional 111,725 acres in the Great Lakes Basin (Figure 4.10).

4.4 DISCUSSION

Examination of the most recent findings of the entire suite of Great Lakes indicators led to the identification of particular themes and management issues. Five general themes emerged: land use, habitat degradation, climate change, toxic contamination and indicator development.

4.4.1 Land Use

Current land use decisions throughout the basin are affecting the chemical, physical, and biological aspects of the ecosystem. Each lake and river assessment presented at SOLEC 2002 cited the need for improved land-use decisions to counter the detrimental effects of urban sprawl and increased population growth. One approach to analyzing land use, the "ecological footprint," has been applied to the Great Lakes Basin by the originators of the approach, Mathis Wackernagel and William Rees (1996). They estimated that an area equivalent to 50% of the land mass of the U.S. is needed to support the current lifestyle of Great Lakes Basin citizens. Managers are keenly aware of the importance of using the most current information when making land-use decisions that may contribute to either the sustenance or degradation of the ecosystem.

4.4.2 Habitat Degradation

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

4.4.3 Climate Change

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

4.4.4 Toxic Contamination

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

4.4.5 Indicator Development

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

4.5 CONCLUSIONS

SOLEC is a framework for organizing ecosystem objectives, for conducting monitoring programs and information management, and for assessing and reporting on the integrity of the Great Lakes. The list of Great Lakes indicators that is reported on through the SOLEC process is dynamic, and indicators may be added or dropped as required by Great Lakes managers.

The entire suite of indicators addresses most of the Great Lakes multiple ecosystem components, yet the overall assessment of the condition of the Great Lakes ecosystem remains incomplete. Some of the reported indicators make use of data that are available, consistent over years and geographic coverage, and reflect basin-wide conditions. For other reported indicators, data are not readily available, are not available as a time series, or are not consistent either over time or across geographic areas. Additionally, within the proposed suite of Great Lakes indicators, there are many that have yet to be reported. They may require further development, refinement of the specific metric being measured, or testing in more local areas before being applied to the Great Lakes Basin. In some cases, existing monitoring programs may require adaptation, or new monitoring efforts need to be initiated.

Several challenges remain to fully implement reporting based on indicators. Networking and collaboration are necessary to decide on a set of indicators, and then various levels of government must ultimately accept the list of indicators. Also, appropriate monitoring and reporting activities must be built into existing Great Lakes programs. Finally, indicators must be reported on in a format that will meet the needs of multiple users. For instance, the managers from Great Lakes government and nongovernmental entities may need specific, scientific details of a particular indicator or group of indicators, whereas upper level administrators, policy makers and the public need a summarized or simplified version of the indicators. One approach to meeting this challenge is to report the same information in different formats and levels of detail. The current reporting mechanism associated with SOLEC includes the State of the Great Lakes report, an accompanying technical report with unabridged indicator reports and complete citations, and fact sheets, which address specific public concerns in a simplified format.

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