Managing *for* Healthy Ecosystems

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CHAPTER 70

Environmental and Socioeconomic Indicators of Great Lakes Basin Ecosystem Health

Paul Bertram, Harvey Shear, Nancy Stadler-Salt, and Paul Horvatin

INTRODUCTION

The purpose of the Great Lakes Water Quality Agreement (GLWQA) between the U.S. and Canada is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem (U.S. and Canada, 1987). The U.S. and Canada have 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 insults to the ecosystem. Environmental management agencies are now being asked to demonstrate that past remediation programs have been successful and that the results of future or continuing programs will be commensurate with the resources expended (financial and personnel time). The demand for high quality data is forcing environmental and natural resource agencies, which operate with limited resources, to be more selective and more efficient in the collection and analysis of data.

Assessing the health of something as large and complex as the Great Lakes basin ecosystem is a significant challenge. The lakes themselves contain one-fifth of the world's fresh water with over 10,000 miles (17,000 km) of shoreline. The basin consists of over 200,000 square miles (520,000 km^2) of land, and about 33.5 million people reside within the basin. The basin is governed by 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 nongovernment organizations, academia, industry, and individual citizens — to work together within a consistent framework to assess and monitor changes in the state of the ecosystem.

In this context, the information collected can be characterized within a series of indicators. 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 U.S., 1999). 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. Used alone or in combination, indicators provide the means to assess progress toward 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 leads toward achievement of higher order goals and vision for the ecosystem (Figure 70.1).

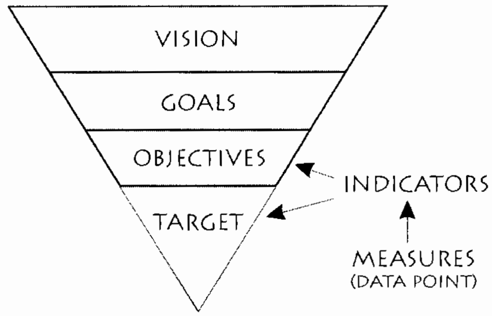


Figure 70.1 Conceptual model of the relationships among indicators, measures, targets, objectives, goals, and visions. (From Canada and the U.S., *State of the Great Lakes 1999*, www.on.ec.gc.ca/solec/ or www.epa.gov/glnpo/solec/98/, Toronto and Chicago, 1999.)

Within the Great Lakes basin, no one organization has the resources or the mandate to examine the state of all the ecosystem components. However, dozens of organizations and thousands of individuals routinely 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, and to measure progress toward ecosystem goals, would facilitate more efficient monitoring and reporting programs. The relative strengths of the agencies could be utilized to improve the timeliness and quality of the data collection and the availability of the information to multiple users.

The State of the Lakes Ecosystem Conferences (SOLEC) were established by the governments of Canada and the U.S. in 1992 in response to reporting requirements of the GLWQA. The conferences are to provide biennial science-based reporting on the state of health of the Great Lakes basin ecosystem.

In the first SOLEC (1994), the governments reported on basin-wide conditions relating to aquatic ecosystem health, human health, aquatic habitat and wetlands, nutrients, contaminants, and the economy. These categories ensured that major components of the ecosystem were assessed, as well as a major component of human activity (the economy). The organizers developed a series of *ad hoc* indicators to provide an assessment of the state of these components and to assess progress toward the goals of the GLWQA. These indicators were based on the best professional judgment of a number of scientists and managers who had prepared background papers on the subject components (U.S. and Canada, 1995). A similar process was followed for SOLEC '96, in which the focus was on the nearshore aquatic and terrestrial environments (Canada and U.S., 1997).

For SOLEC '98, the organizers wanted to support the further development of easily understood indicators that 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 ecosystem components and the progress being made to remedy existing problems.

INDICATOR SELECTION PROCESS

To guide the development of a suite of indicators for the Great Lakes basin ecosystem, a series of organizing principles was recognized.

- *Build upon the work of others.* There has been a long history of monitoring and of the development of indicators for the Great Lakes. For example, indicators have been proposed in some form by the International Joint Commission, the Great Lakes Fishery Commission, Lakewide Management

Plans, and in the background papers prepared for SOLEC '94 and SOLEC '96. The intent for the SOLEC process was to make use of the work that has gone on before rather than repeat it.

- *Focus on broad spatial scales.* SOLEC indicators are intended to reflect conditions on the scale of the whole Great Lakes basin, whole lake watersheds, and subbasins of the larger lakes. Indicators for local geographic areas are reported through other programs.
- *Select a framework for subdividing the Great Lakes basin ecosystem.* SOLEC indicators were developed within the framework of geographic zones (offshore, nearshore, coastal wetlands, nearshore terrestrial) and nongeographic issues (human health, land use, societal, and unbounded). This framework provides flexibility to incorporate the main elements of other frameworks. For example, physical, chemical, and biological status can be assessed within each geographic zone.
- *Select a system for types of indicators.* There are several classification schemes or models for indicators (for example, GMIED, 1998; IJC, 1991, 1996; Messer, 1992; Regier, 1992), one of which is the State-Pressure-Human Activity (Response) model. This S-P-A model is simple and broadly applicable. *State* indicators address the state of the environment, the quality and quantity of natural resources, and the state of human and ecological health. *Pressure* indicators describe natural processes and the results of human activities that impact, stress, or pose a threat to environmental quality. *Human activity (response)* 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.
- *Identify criteria for indicator selection.* The primary criteria that were used for the selection of the suite of indicators were: *necessary, sufficient,* and *feasible.* For individual indicators, a set of 21 additional criteria was identified. Not all indicators scored high for all criteria. However, for any given indicator, the more criteria that were met, the stronger the case for including that indicator on the proposed SOLEC list (Bertram and Stadler-Salt, 1999).

A group of experts was assembled to review, select, and refine Great Lakes indicators. Some members of this indicators group were also leaders of seven core groups, one for each of the SOLEC indicator categories mentioned above. The core groups were composed of expert panels who participated either directly with hands-on selection and development of indicators, or by reviewing draft products throughout the process. Over 130 people were involved in some way in this project.

The core groups studied documents from multiple sources that identified or discussed ecosystem objectives or environmental indicators. More than 850 indicators were identified through this process. The indicators were then screened according to the criteria, and appropriate indicators were identified. In many cases, indicators from the existing list were modified or combined, or new indicators were developed to create the proposed suite of 80 SOLEC indicators.

For each of the SOLEC indicators, detailed descriptive information was assembled into a metadatabase. The information included the following (Bertram and Stadler-Salt, 1999):

- Environmental measurements to be taken
- Environmental components the indicator would be used to assess
- Ecosystem objectives the indicator would be addressing
- Indicator desired end points or reference values
- Descriptions of the indicator's features and limitations
- Illustrations of how the indicator would be presented and interpreted
- Additional comments that would clarify the intent and implementation of the indicator

The list of 80 indicators (Table 70.1) addresses all of the SOLEC categories. Most of the indicators (84%) reflect the state of the ecosystem component or stresses on the ecosystem rather than human activities. The indicators also have applicability to broad environmental compartments (air, water, sediments, land, biota, fish, and humans) and to issues of human concern (toxic substances, nutrients, nonnative species, habitat, climate change, and stewardship). A full description of the indicators can be found in Bertram and Stadler-Salt (1999), which is available online at www.on.ec.gc.ca/solec/solec2000 or www.epa.gov/glnpo/solec/98/.

Table 70.1 Indicators Developed for Each of the SOLEC Groupings, with Cross-Referenced Applicability to Other Groupings of Indicator Type, Environmental Compartments, and Issues

	Indicator Type			Environmental Compartment							Issues					
Indicator Name	State	Pressure	Human Activity	Air	Water	Land	Sediments	Biota[a]	Fish	Humans	Contaminants[b]	Nutrients	Nonnative Species	Habitat	Climate Change	Stewardship
Open and Nearshore Water Indicators																
Lake trout and *Diporeia hoyi*	x							x	x		x	x	x	x		
Toxic chemical concentrations in offshore waters		x			x						x					
Atmospheric deposition of toxic chemicals		x		x	x						x					
Fish habitat	x				x				x					x		
Salmon and trout	x								x		x	x	x	x		
Preyfish populations	x								x		x	x	x	x		
Walleye and *Hexagenia*	x							x	x		x	x	x	x		
Phytoplankton populations	x							x			x	x	x			
Zooplankton populations	x							x			x	x	x			
Benthos diversity and abundance	x							x			x	x		x		
Native unionid mussels	x							x					x			
Sea lamprey		x							x				x			
Contaminants in colonial nesting waterbirds		x						x			x					
Concentrations of contaminants in sediment cores		x					x				x					
Contaminant exchanges between media: air to water and water to sediment		x		x	x		x				x					
Phosphorus concentration and loadings		x			x							x				
Deformities, eroded fins, and lesions and tumors (DELT) in nearshore fish	x								x		x					
Contaminants in young-of-the-year spottail shiners		x							x		x					
Wastewater pollution		x			x						x	x				
Sediment available for coastal nourishment	x				x		x							x		
Coastal Wetland Indicators																
Coastal wetland area by type	x				x	x								x		
Coastal wetland invertebrate community health	x							x						x		
Amphibian diversity and abundance	x							x						x		
Wetland-dependent bird diversity and abundance	x							x						x		
Presence, abundance, and expansion of invasive plants	x							x					x	x		
Coastal wetland fish community health	x								x				x	x		
Deformities, eroded fins, lesions and tumors (DELT) in coastal wetlands fish	x								x		x					
Contaminants in shaping turtle eggs		x						x			x					

Table 70.1 (continued) Indicators Developed for Each of the SOLEC Groupings, with Cross-Referenced Applicability to Other Groupings of Indicator Type, Environmental Compartments, and Issues

	Indicator Type			Environmental Compartment							Issues					
Indicator Name	State	Pressure	Human Activity	Air	Water	Land	Sediments	Biota[a]	Fish	Humans	Contaminants[b]	Nutrients	Nonnative Species	Habitat	Climate Change	Stewardship
Nitrates and total phosphorus into coastal wetlands		x			x							x				
Sediment flowing into coastal wetlands		x			x		x							x		
Effects of water level fluctuations		x			x									x	x	
Gain in restored coastal wetland area by type			x		x	x								x		x
Nearshore Terrestrial Indicators																
Area, quality, and protection of lakeshore communities	x					x		x						x		x
Extent and quality of nearshore natural land cover	x					x								x		
Nearshore land use	x					x								x		
Nearshore species diversity and stability	x							x					x			
Extent of hardened shoreline		x				x								x		
Artificial coastal structures		x				x								x		
Nearshore plant and animal problem species		x						x					x	x		
Contaminants affecting productivity of bald eagles		x						x			x					
Contaminants affecting the American otter		x						x			x					
Protected nearshore areas			x			x								x		x
Shoreline managed under integrated management plans			x			x										x
Community/species plans			x					x								x
Land Use Indicators																
Habitat fragmentation	x					x								x		
Habitat adjacent to coastal wetlands	x					x								x		
Urban density	x					x										
Land conversion		x				x										
Mass transportation		x		x		x									x	x
Sustainable agricultural practices			x			x										x
Brownfield redevelopment			x			x										x
Green planning process			x		x	x										x
Human Health Indicators																
Geographic patterns and trends in disease incidence	x									x						
Chemical contaminant intake from air, water, soil, and food		x								x	x					
Chemical contaminants in human tissue		x								x	x					
Contaminants in edible fish tissue		x							x		x					

(continued)

Table 70.1 (continued) Indicators Developed for Each of the SOLEC Groupings, with Cross-Referenced Applicability to Other Groupings of Indicator Type, Environmental Compartments, and Issues

	Indicator Type			Environmental Compartment							Issues					
Indicator Name	State	Pressure	Human Activity	Air	Water	Land	Sediments	Biota[a]	Fish	Humans	Contaminants[b]	Nutrients	Nonnative Species	Habitat	Climate Change	Stewardship
Human Health Indicators (continued)																
Contaminants in recreational fish		x							x		x					
Drinking water quality		x			x			x			x	x				
Escherichia coli and fecal coliform levels in nearshore recreational waters		x			x			x			x					
Radionuclides		x		x	x						x					
Air quality		x		x							x					
Societal Indicators																
Aesthetics	x									x						x
Economic prosperity	x															
Water withdrawal		x			x					x						x
Energy consumption		x		x						x					x	x
Solid waste generation		x		x		x				x	x				x	x
Capacities of sustainable landscape partnerships			x							x						x
Organizational richness of sustainable landscape partnerships			x							x						x
Integration of ecosystem management principles across landscapes			x							x						x
Integration of sustainability principles across landscapes			x							x						x
Citizen/community place-based stewardship activities			x							x						x
Financial resources allocated to Great Lakes programs			x							x						x
Unbounded Indicators																
Breeding bird diversity and abundance	x							x						x		
Threatened species	x							x	x				x	x		
Climate change: number of extreme storms		x													x	
Climate change: first emergence of water lily blossoms in coastal wetlands		x						x							x	
Climate change: ice duration on the Great Lakes		x			x										x	
Acid rain		x		x	x	x					x					
Nonnative species		x						x	x				x			
Count	30	35	13	9	19	19	4	23	13	13	29	11	13	27	7	19

[a] Excluding fish and humans.
[b] Including pathogens.

Because SOLEC conferences are multiagency, multijurisdictional reporting venues, the SOLEC indicators require acceptance by a broad spectrum of stakeholders in the Great Lakes basin. The indicator descriptions were widely circulated for review and revision several times, and most proposed indicators have been accepted by consensus. The indicator list will remain dynamic, however, and it will continue to evolve.

IMPLEMENTING SOLEC INDICATORS

As capacity to monitor and report on the 80 indicators builds over the next several years, a more complete answer to the questions posed by the public about the health of the Great Lakes will emerge. For example, 19 of the 80 indicators are directly concerned with the waters of the Great Lakes (Table 70.1). By analyzing the monitoring data of those indicators and aggregating the results, a picture of the health of the waters of the Great Lakes should emerge. Gaps will no doubt be identified that require both an adjustment in the number of indicators needed and a fine tuning of the indicators in order to more fully describe the state of the waters. This will be true for the other environmental compartments and issues as well.

Currently, however, data are not available for all 80 indicators. The example indicators presented here represent each of the SOLEC organizational groupings. For each indicator, a short overview is followed by a description of the indicator, with examples of the data available for that indicator.

Nearshore and Open Waters Indicators

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

- High density patterns of settlement, development, and population growth leading to the release of contaminants and nutrients, as well as habitat loss
- Agricultural development in the southern portion of the basin, which created an abundance of food and fiber leading to 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
- Nonnative species invasions, often facilitated by the construction of canals
- Development of sheltered areas into marinas and deepwater ports

The open waters of the Great Lakes are all of the waters beyond the lakeward edge of the nearshore waters (Edsall and Charlton, 1997). The offshore waters of the Great Lakes are also subject to many of these same stresses plus some unique offshore issues, such as atmospheric deposition of contaminants, the alteration of fish communities, and loss of biodiversity associated with overfishing and fish stocking practices.

Sea Lamprey

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

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 has invaded all the Great Lakes in a span of 110 years, 1835 to 1946 (Mills et al., 1993).

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 (Klar et al., 1996).

The information presented in Figure 70.2 shows sea lamprey populations (in their spawning phase) throughout the Great Lakes. During the past 20 years, Lake Superior populations have remained at levels less than 10% of peak abundance. For Lake Michigan, populations have been relatively stable, but an increase has been seen in northern sections of the lake due to the large population in Lake Huron moving into Lake Michigan. Lake Huron populations have remained at very high levels since the early 1980s because of large spawning populations in the St. Marys River. An integrated control strategy was initiated in the St. Marys River in 1997 which includes

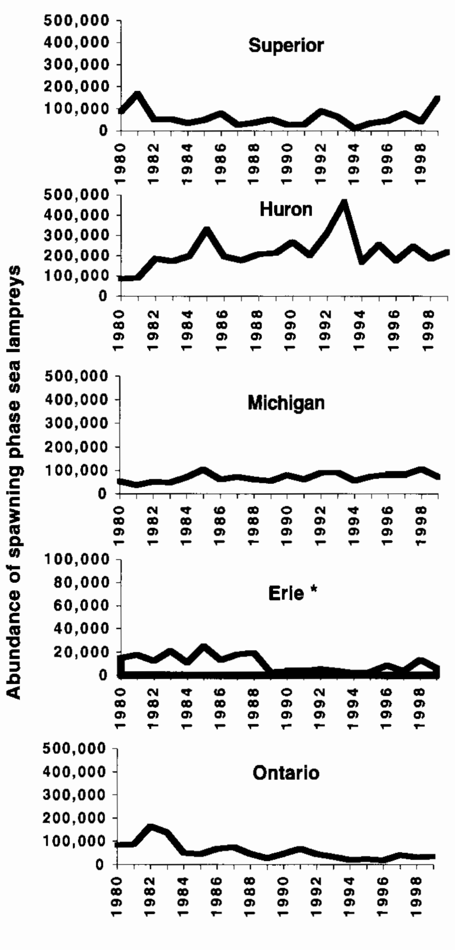


Figure 70.2 Total abundance of sea lamprey in each of the five Great Lakes estimated during the spawning phase. (From Canada and the U.S., *State of the Great Lakes 2001*, www.binational.net, Toronto and Chicago, 2001.)

the targeted application of a new bottom-release lampricide, enhanced trapping of spawning animals, and sterile-male release. In Lake Erie, lamprey abundance has increased since the early 1990s. Sources of this increase were several streams to which treatment has been deferred due to low water flows or concerns for nontarget organisms. Lake Ontario populations have remained constant in recent years because of adequate control.

Future pressures include the increased potential for sea lamprey to colonize new locations due to improved water quality in Great Lakes tributaries. Additionally, short lapses in lamprey control can result in quick increases in abundance. Significant additional control efforts, like those on the St. Marys River, may be necessary to maintain reduced lamprey populations.

Phosphorus Concentrations and Loadings

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

Sewage treatment plant effluent, agricultural runoff, and industrial processes have released high concentrations of phosphorus into the lakes (IJC, 1996). Strict phosphorus loading targets implemented in the 1980s have been successful in reducing nutrient concentrations in the lakes (Figure 70.3), although high concentrations still occur locally in embayments and harbors (Canada and U.S., 1999).

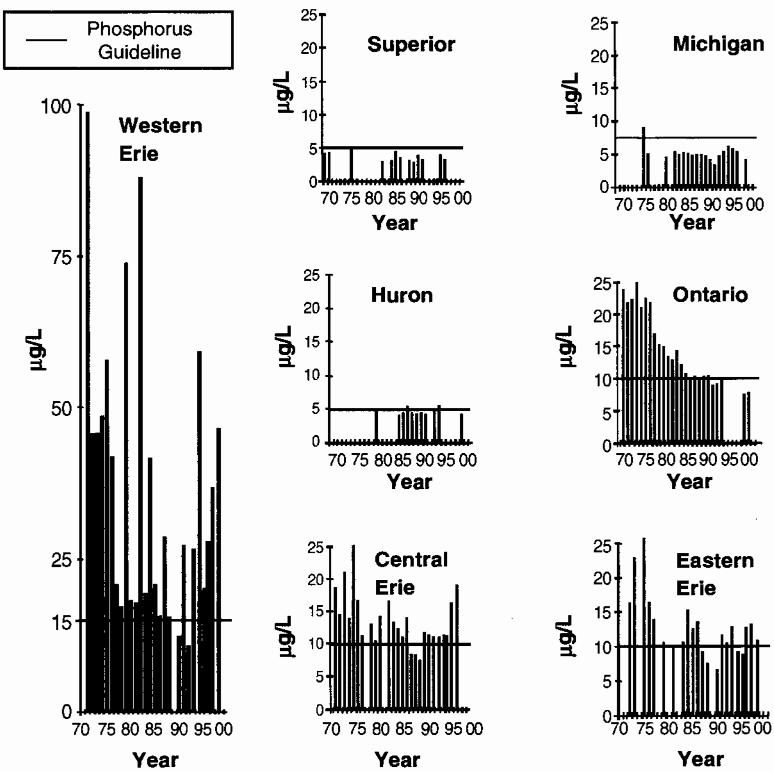


Figure 70.3 Total phosphorus trends in the Great Lakes 1971–2000. Data reflect samples collected at the surface from offshore waters during spring. Blank indicates no sampling (From Canada and the United States, *State of the Great Lakes 2001*, www.binational.net, Toronto and Chicago, 2001.)

Concentrations of total phosphorus in the open waters of the Great Lakes have remained nearly stable since the mid-1980s. Concentrations in the open waters of Lakes Superior, Michigan, Huron, and Ontario are at or below guideline levels. Concentrations in all three basins of Lake Erie exceed phosphorus guidelines, and recent data suggest an increasing trend. This trend may be related to the large populations of nonnative zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*).

With the anticipated human population growth in the basin over the next 25 years (up to 2 million in Canada alone), the nutrient loads to the lakes from this population will be significant and they will require additional treatment, particularly at sewage treatment plants. The phosphorus indicator will be of value in helping governments track trends in nutrients in the lakes and adjust management strategies accordingly.

Coastal Wetland Ecosystem Indicators

Wetlands are important ecologically, socially, and economically and are one of the most productive ecosystems in the world (Maynard and Wilcox, 1997). Despite these values, coastal wetlands are in trouble. Threats include regulation of lake water levels, land-use change, nonnative species, and toxic chemicals.

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
- Risk factors or human-induced pressures at an acceptable level

There are few existing monitoring programs for Great Lakes coastal wetlands. Efforts are being 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

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

Birds are among the most visible and diverse groups of wildlife in Great Lakes coastal 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.

Patterns in the species composition and numbers of breeding wetland birds may reflect changes in the condition of breeding habitats. Five years of Marsh Monitoring Program (MMP, www.bsc-eoc.org) data provided information on numbers of marsh nesting birds. Basin-wide increases were observed for Canada goose, mallard, chimney swift, northern rough-winged swallow, common yellowthroat and common grackle (Table 70.2). Basin-wide declines were observed for pied-billed grebe, blue-winged teal, American coot, and black tern. Each of the declining species depends on wetlands for breeding, but because they use wetland habitats almost exclusively, the pied-billed grebe, American coot, and black tern are particularly dependent on the availability of healthy wetlands.

Continuing and future pressures on these bird species include the continued loss and degradation of wetlands, water level stabilization, sedimentation, contaminant and nutrient inputs, and the invasion of nonnative plants and animals.

Table 70.2 Estimated Annual Percent Changes in Population Indices of Marsh-Nesting and Aerial Foraging Bird Species Detected on Great Lakes Basin Marsh Monitoring Program (MMP) Routes, 1995–1999

Species	% Change	95% Confidence Limits
Canada goose	20.2	4.9, 37.7
Mallard	29.2	17.0, 42.6
Chimney swift	15.8	1.7, 31.8
Northern rough-winged swallow	20.1	0.8, 43.1
Common yellowthroat	6.8	2.0, 11.7
Common grackle	42.5	27.1, 59.7
Pied-billed grebe	–11.8	–19.9, –2.5
Blue-winged teal	–13.2	–24.3, –0.5
American coot	–22.1	–34.7, –7.2
Black tern	–20.2	–28.7, –10.8

Population indices are based on counts of individuals inside the MMP station boundary and are defined relative to 1999 values (see Canada and U.S., 2001).

Nearshore Terrestrial Ecosystem Indicators

The nearshore terrestrial environment is an integral part of the Great Lakes basin ecosystem, the extent of which is defined by the lakes themselves. A description of these areas and major stresses on these natural communities are described in *State of the Great Lakes 1997* (Canada and U.S., 1997).

Thirteen indicators of nearshore terrestrial ecosystem health have been developed to fulfill the need for a cost-effective and easily understood set of measures that will describe how nearshore ecosystems across the basin are changing, identify what is causing the changes, describe the current status of these ecosystems and component parts, and evaluate how effectively humans are responding to the changes.

Area, Quality, and Protection of Alvar Communities

This indicator was designed to measure the area, quality, and protected status of the alvar communities occurring within 1 km of the shoreline. Alvar communities are naturally open habitats occurring on flat limestone bedrock. The information collected to satisfy this measure may also help to identify the sources of threats to these ecologically significant habitats, as well as the success of management activities associated with the protection status.

More than 90% of the original extent of alvar habitats has been destroyed or substantially degraded. Emphasis is focused on protecting the remaining 10%. Approximately 64% of the remaining alvar area exists within Ontario; 16% in New York State; 15% in Michigan; and smaller areas in Ohio, Wisconsin, and Quebec. Less than 20% of the nearshore alvar acreage is currently fully protected, while over 60% is at high risk (Figure 70.4). 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.

Continuing pressures on alvars include:

- Habitat fragmentation and loss
- Trails
- Off-road vehicles
- Resource extraction uses such as quarrying or logging
- Adjacent land uses such as residential subdivisions
- Grazing or deer browsing,
- Plant collection for bonsai and other hobbies
- Invasion by nonnative plants

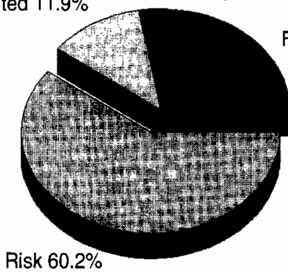


Figure 70.4 Protection status of Great Lakes nearshore alvar communities, 2000 (Canada and the U.S., *State of the Great Lakes 2001*, www.binational.net, Toronto and Chicago, 2001.)

Land-Use Indicators

Changing patterns of land use are a major ecosystem stressor for the Great Lakes basin and its nearshore areas. 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.

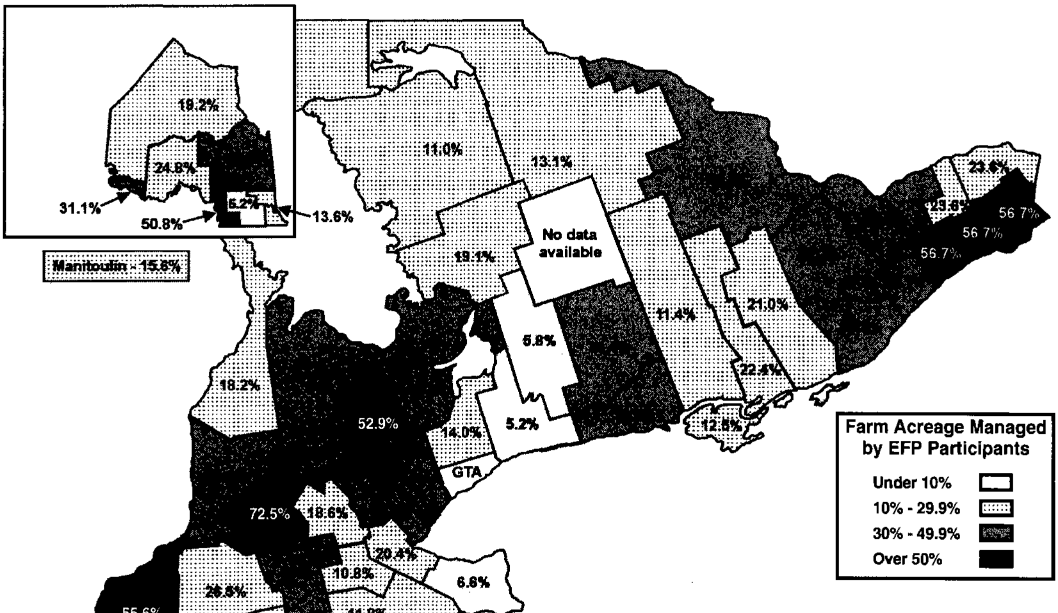
Sustainable Agricultural Practices

This indicator assesses the number of environmental and conservation farm plans and environmentally friendly practices in place, such as integrated pest management to reduce the unnecessary use of pesticides, conservation tillage and other soil preservation practices to reduce energy consumption, and prevention of ground and surface water contamination.

Agriculture accounts for 35% of the land area of the Great Lakes basin and dominates in the southern portion of the basin. In the past, excessive tillage and intensive crop rotations led to soil erosion and the resulting sedimentation of major tributaries. Agriculture is a major user of pesticides with an annual use of 26,000 tons. These practices led to a decline of soil organic matter. The adoption of more environmentally responsible practices has helped to replenish carbon in the soils to 60% of turn-of-the-century levels. The following are two examples of voluntary programs to encourage the development and implementation of environmental farm plans.

In Ontario, farmers can complete an Environmental Farm Plan identifying environmental areas of concerns on their farms and note activities and specific actions they will take to remediate them. For example, ensuring that farm manure is managed to avoid contaminating surface water courses and groundwater is critical to maintaining 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. 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 70.5 depicts the percentage of acreage with approved Environmental Farm Plans in Ontario.

The U.S. Department of Agriculture (USDA) offers landowners financial, technical, and educational assistance to implement conservation practices on privately owned land and promote sustainable agricultural practices. 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



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

Figure 70.5 Ontario Environmental Farm Plans (EFP). (From Canada and the U.S., *State of the Great Lakes 2001*, www.binational.net, Toronto and Chicago, 2001.)

encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as tame or native grasses, wildlife plantings, trees, filter strips, or riparian buffers. Figure 70.6 shows the number of acres with conservation planned systems in place.

Human Health Indicators

Many people consider the protection of human health to be one of the more important goals of environmental management. Consequently, there is interest in indicators of 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. Indicators are also needed to assess the effectiveness of social, economic, health, and environment policies and actions to protect or improve the health of the Great Lakes basin population.

Because the ability to relate the state of human health in the Great Lakes basin to components of the Great Lakes ecosystem per se is difficult at best, the effort to develop human health indicators has focused primarily on exposure to environmental contaminants and pathogens. The indicators include 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); and 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. Using an indicator that analyzes geographic patterns and trends in incidence rates, however, can serve to identify potential areas of concern and may lead to testable hypotheses regarding the correlation of environmental exposure with human disease.

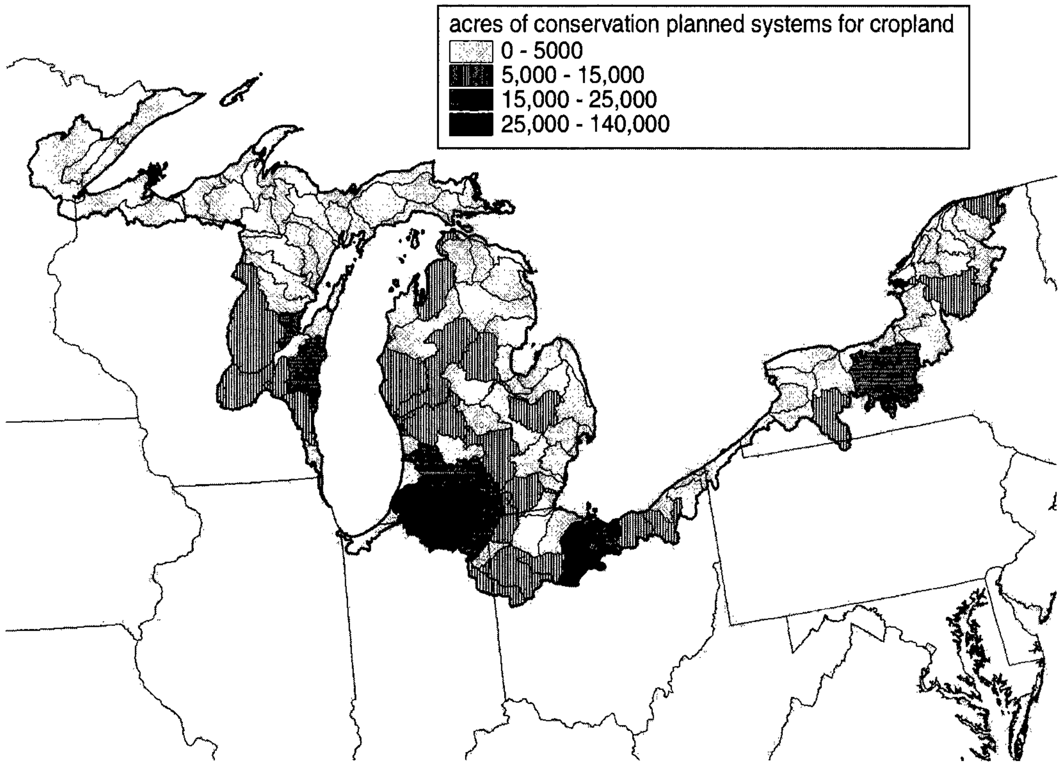


Figure 70.6 Annual U.S. Conservation Planned Systems for 2000. (From Canada and the U.s., *State of the Great Lakes 2001*, www.binational.net, Toronto and Chicago, 2001.)

Escherichia coli *and Fecal Coliform Levels in Nearshore Recreational Waters*

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

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 runoff, and poorly treated sewage. Gastrointestinal disorders and minor skin, eye, ear, nose, and throat infections have been associated with microbial contamination. Children, the elderly, and people with weakened immune systems are those most likely to develop illnesses or infections after swimming in polluted water.

Survey reports of U.S. beach advisories during the 1998 swimming season (June, July, and August) show that 78% of the reporting beaches were open for the entire 1998 season. Results were similar for Canadian beaches where 79% of the reporting beaches were open the entire season (Figure 70.7). Survey reports of U.S. beach closings or advisories during the 1999 season show that 65% of the reporting beaches were open the entire 1999 season. Several factors may have influenced the apparent increase in percentage of beach closings in 1999 compared with 1998:

- Fewer beach managers responded to survey questionnaires in 1999
- A different mix of beaches was reported in 1999
- More beach managers were using *E. coli* testing in 1999 than in 1998
- An improved system for accounting for beach advisory days was used in 1999

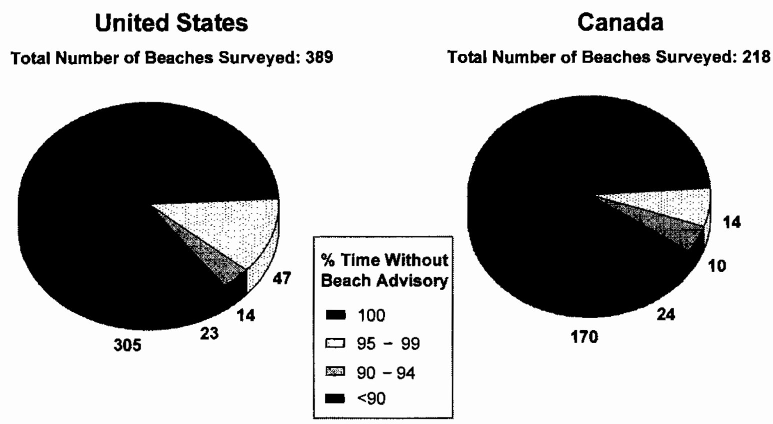


Figure 70.7 Comparison of the frequency of U.S. and Canadian beach advisories for Great Lakes beaches, 1998. The swimming season was defined as June, July and August. Data were obtained from voluntary responses by beach managers to annual requests for information. (From Canada and the U.S., *State of the Great Lakes 2001*, www.binational.net, Toronto and Chicago, 2001.)

While the actual water quality near beaches may not have changed, the increase in beach advisory days is believed to be more protective of human health.

Societal Indicators

Human society is part of the ecosystem, and integrated environmental management requires human activities to be respectful of other ecosystem components. For example, the creation and discharge of waste materials by humans may have an impact on both the habitat and the health of plant and animal species. A responsible society will recognize its collective impact on the surrounding environment, and it will seek to sustain ecosystem integrity indefinitely.

Within the suite of proposed Great Lakes indicators, sustainability is implicit throughout. A set of indicators to assess human activities and other societal issues, however, would reflect our individual and collective actions to halt, mitigate, adapt to, or prevent damage to the environment. Socioeconomics, urban issues, societal responsibility, and other social aspects of Great Lakes communities are not easy to monitor due to the complexity of the relationships between jurisdictions and the lack of coordinated monitoring programs. The SOLEC process is being used to engage a variety of agencies and organizations in the Great Lakes basin to participate in the further selection and implementation of clear, understandable societal indicators.

Economic Prosperity

This indicator assesses the unemployment rates within the Great Lakes basin and, when used in association with other societal indicators, infers the capacity for society in the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem. During periods of low unemployment and economic well-being, public support for environmental initiatives by government agencies may be increased.

By most measures, the binational Great Lakes regional economy is reasonably healthy. The unemployment rate for the Great Lakes states was less than the U.S. national average for most of the 1990s. Canadian and Ontario economic recoveries unfolded later than the U.S., but Ontario unemployment rates in 2000 were at the lowest level since 1990.

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

The overall message is mixed. Good economic times can translate into high levels of consumer spending and home buying, which can lead to increased household waste generation, increased air pollution, and accelerated land use changes.

Unbounded Indicators

Several proposed indicators do not fit neatly into any of the other SOLEC ecological categories. These indicators may have application to more than one of the other organizing categories, or they may reflect issues that affect the Great Lakes but have global origins or implications. For example, indicators related to climate change will affect all the groups yet truly belong in none of them.

Nonnative Species

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

Since the 1830s, there have been 63 nonnative aquatic animal (fauna) species introduced into the Great Lakes that have maintained permanent, breeding populations (Figure 70.8). In almost the same time frame, 83 nonnative plant (flora) species were introduced and established residency.

Some of the main entry mechanisms include ship ballast water, the deliberate release of fish and other faunal species, and releases from hobby aquaria. Some plant species have escaped from cultivation. Even with voluntary and mandatory ballast exchange programs recently implemented in Canada and the U.S., newly introduced species associated with shipping activities have been identified.

Introductions of nonnative species are expected to continue because of increased global trade, new diversions of water into the Great Lakes, aquaculture industries, and changes in water quality and temperature. Even the presence of some key nonnative species could make the Great Lakes more hospitable for other nuisance species.

CONCLUSION

The process for selecting and developing indicators of the health of the Great Lakes basin ecosystem has been open but rigorous, engaging the participation of a wide variety of stakeholders.

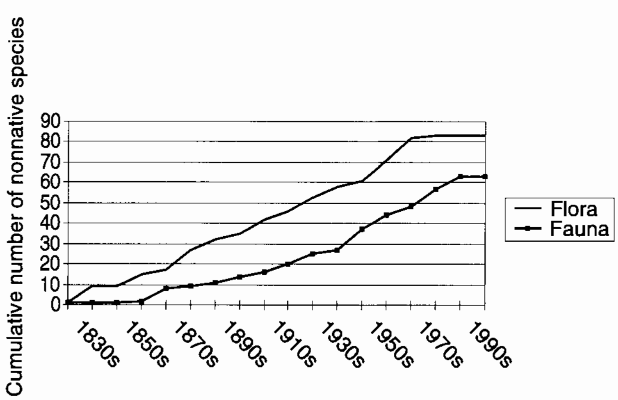


Figure 70.8 Cumulative number of nonnative species introduced into the Great Lakes since the 1830s (From Canada and the U.S., *State of the Great Lakes 2001*, www.binational.net, Toronto and Chicago, 2001.)

Informal consensus on the suite of indicators has been actively sought, and it continues to be important as the indicators are reviewed and refined. The indicators have been extensively reviewed, but the list continues to be dynamic, and individual indicators are subject to testing and further revision.

Based on the overall criteria of *necessary* and *sufficient*, the suite of SOLEC indicators addresses most of the Great Lakes ecosystem components. Some additional indicators may be added as information gaps or other managerial needs for data are identified. Some indicators may also be removed from the list if they no longer provide useful information.

Monitoring and reporting on the state of ecosystem components is not a new concept to Great Lakes programs. The value added by the SOLEC process is the deliberate selection of information requirements and the translation of those requirements into a comprehensive suite of indicators for multiple users. The data collected from collaborative monitoring efforts and the subsequent interpretation of the data should be useful for environmental managers at all levels of government as well as for researchers, industry, and private citizens. The suite of indicators can also be used by the governments of Canada and the U.S. not only as a basis for reporting on progress toward the goals of the GLWQA, but also as a basis for engaging additional monitoring and research.

Several challenges remain to implement fully the SOLEC indicators and the SOLEC reporting venues. They include the following:

- Periodically reviewing and refining the indicator list.
- Gaining acceptance of the list by federal, state, provincial, and municipal partners who have 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 indicators at future SOLEC conferences and in printed reports or other media in a format that will meet the needs of multiple users.

As more of the underlying data supporting the indicators become available, more audiences can be served, including the general public, local decision makers, and the scientific and engineering community. A well-informed public should facilitate the management decisions and actions that are needed to continue progress toward the goals of the Great Lakes Water Quality Assessment.

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