

# **State of the Lakes Ecosystem Conference 1998**

## **Selection of Indicators for Great Lakes Basin Ecosystem Health**

**Version 3**

*Draft for Review*

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May 1999



# Table of Contents

|       |  |    |
|-------|--|----|
| 1.0   | Introduction                                 | 1  |
| 1.1   | History of SOLEC                             | 1  |
| 2.0   | Indicators                                   | 2  |
| 2.1   | What is an Indicator?                        | 2  |
| 2.2   | Types of Indicators                          | 3  |
| 2.3   | Scale  | 3  |
| 2.4   | The Need for an Indicator List               | 3  |
| 2.5   | Why Should There be Agreement on Indicators? | 4  |
| 3.0   | The Process for Selecting SOLEC Indicators   | 5  |
| 3.1   | Pre-SOLEC 98                                 | 5  |
| 3.2   | SOLEC 98                                     | 7  |
| 3.3   | Post-SOLEC 98                                | 7  |
| 3.4   | The SOLEC Indicators Database                | 8  |
| 4.0   | Indicator Core Groups                        | 9  |
| 4.1   | Nearshore and Open Waters                    | 9  |
| 4.1.1 | The Indicator Selection Process              | 9  |
| 4.1.2 | Problems Encountered                         | 10 |
| 4.1.3 | Open and Nearshore Waters Indicators         | 10 |
| 4.2   | Coastal Wetlands                             | 12 |
| 4.2.1 | The Indicator Selection Process              | 13 |
| 4.2.2 | Problems / Unresolved Issues                 | 13 |
| 4.2.3 | Coastal Wetland Indicators                   | 15 |
| 4.3   | Nearshore Terrestrial                        | 16 |
| 4.3.1 | The Indicator Selection Process              | 16 |
| 4.3.2 | Nearshore Terrestrial Indicators             | 17 |
| 4.5   | Land Use                                     | 19 |
| 4.5.1 | The Indicator Selection Process              | 19 |
| 4.5.2 | Land Use Indicators                          | 19 |
| 4.4   | Human Health                                 | 21 |
| 4.4.1 | The Indicator Selection Process              | 21 |
| 4.4.2 | Human Health Indicators                      | 22 |
| 4.6   | Societal                                     | 23 |
|       | Stewardship and Sustainability               | 23 |
| 4.6.1 | The Indicator Selection Process              | 24 |
| 4.6.2 | Societal Indicators                          | 25 |

## Appendices

- Appendix 1 — SOLEC Indicator List - Descriptors
- Appendix 2 — Listing of All Indicators Entered into Database
- Appendix 3 — Relevancies (or Alternate Indicator Groupings)
- Appendix 4 — Criteria
- Appendix 5 — SOLEC Indicator Database
- Appendix 6 — Definitions and Acronyms
- Appendix 7 — Referenced Documents
- Appendix 8 — Indicator Group, Core Group Members and SOLEC 98 Steering Committee Members
- Appendix 9 — Revisions Since Version 2 of the SOLEC 98 Indicator List



## **Notice to Readers**

*The concepts and ideas contained in this paper were assembled for discussion at SOLEC 98 (October 21-23, 1998). The SOLEC deliberations were an important step in the process of developing a suite of indicators to use in determining the health of the Great Lakes basin ecosystem. Participants were encouraged to review the SOLEC 98 document prior to SOLEC and provide comments, specific information and / or references during the breakout sessions, on the comment forms or to the authors. These comments have been considered during the preparation of this revised post-conference SOLEC Indicator List (Version 3).*

*The major changes in this report include the deletion of a few indicators, additions of a few others, revisions to the indicator descriptors of all, summary of a criteria assessment and the inclusion of a section of the different ways the SOLEC indicators may be sorted and organized.*

The Parties to the GLWQA want to establish a consistent, easily understood suite of indicators that will objectively represent the state of major ecosystem components across all Great Lakes basins which the Parties can use to report progress every two years. This suite of indicators should also be used to assess the Parties regarding achievement of the purpose of the GLWQA.

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# SOLEC 98

## Selection of Indicators For Great Lakes Ecosystem Health

### 1.0 Introduction

#### 1.1 History of SOLEC

The State of the Lakes Ecosystem Conferences (SOLEC) are hosted by the U.S. Environmental Protection Agency and Environment Canada, every two years on behalf of the two countries in response to the Great Lakes Water Quality Agreement (GLWQA). Canada and the United States are known as the Parties to the GLWQA. SOLEC conferences are intended to focus on the condition of the Great Lakes ecosystem and the major factors impacting it, and to provide a forum for exchange of this information. These conferences are not intended to discuss the status of programs needed for its protection and restoration. Another goal of the conferences is to reach a large audience of people in all levels of the government, corporate, and not-for-profit sectors who make decisions that affect the Lakes.

The conferences are the focal point of a process of gathering information from a wide range of sources and engaging a variety of organizations in bringing it together. In the year following each conference the Governments have prepared a report on the state of the Lakes based in large part upon the conference process.

The first conference, held in 1994, addressed the entire system with particular emphasis on aquatic community health, human health, aquatic habitat, toxic contaminants and nutrients in the water, and the changing Great Lakes economy. The 1996 conference focused on the nearshore lands and waters of the system where biological productivity is greatest and humans have had maximum impact. Emphasis was placed on nearshore waters, coastal wetlands, land by the Lakes, the impact of changing land use, and information availability and management. For both conferences indicators were chosen and, based on expert opinions, subjective assessments were provided as to the conditions in terms of good, fair, poor, etc.

In planning for SOLEC 98 the organizers wanted to support further development of easily understood indicators which objectively represent the condition of the Great Lakes ecosystem components. These would be used every two years to inform the public and report progress in achieving the purpose of the GLWQA: *to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Ecosystem*. The SOLEC indicators would reflect conditions of the whole Great Lakes basin and its major components (a general system-wide overview), and they would draw upon and complement indicators used for more specific purposes such as Lakewide Management Plans (LaMPs) or Remedial Action Plans (RAPs) for Areas of Concern.

## 2.0 Indicators

### 2.1 What is an Indicator?

The concept of indicators is quite familiar. They can be thought of as pieces of evidence, or clues, that tell us something about the condition of something of interest. For example, doctors use blood pressure and weight to gauge human health, and economists use interest rates and housing starts to assess the health of economies. Similarly, environmental indicators provide bits of information that are useful to us to assess our surroundings. Indicators, when tracked over time, provide information on trends in the condition of the surroundings.

Indicators can be thought of as pieces of evidence that help us assess the condition of something of interest.

During the organization of a set of indicators for SOLEC, it became apparent very quickly that a number of related terms and concepts could be confusing. Some basic definitions are presented here to provide the context for the SOLEC indicators project. Additional details and examples can be found in Appendix 6.

- Vision** A general description of the desired state of a lake, geographical area, etc., as expressed by a group of stakeholders.
- Goal** A condition or state desired to be brought about through a course of action. 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 end point or reference values for an indicator that provides the context for assessing whether or not an objective is being met.

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 an end point or reference value. The indicator is intended to be used, alone or in combination with other indicators, to assess progress toward one or more objectives. For SOLEC purposes, the objectives may be expressed in the Great Lakes Water Quality Agreement, LaMPs, RAPs, Fish Community Objectives, or other generally accepted Great Lakes planning documents. In addition, to be widely used by decision-makers and others, indicators should be readily understood by a broad audience.



## 2.2 Types of Indicators

There are several classification schemes for indicators, which encompass everything from human actions (e.g., the number of participants in public hearings) to environmental measurements (e.g., the number of bald eagle fledglings per breeding pair). SOLEC has adopted the State—Pressure—Human Activities (Response) indicator model. This framework is considered one of the most widely accepted classification schemes for environmental indicators because of its simplicity and broad applicability. The SOLEC indicators can be classified according to the following types:

**State (of the Environment):** These indicators address the state of the environment, the quality and quantity of natural resources, and the state of human and ecological health. They reflect the ultimate objective of environmental policy implementation. The indicators are chosen by considering biological, chemical and physical variables and ecological functions.

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

**Human Activities (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. Examples of actions include education, regulation, market incentives, technology changes, etc.

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*. Most SOLEC indicators will be of types State or Pressure, reflecting the focus of the Conference.

## 2.3 Scale

Indicators may be selected to reflect environmental conditions on a variety of scales in both space and time. From a satellite, one can obtain an image of the entire Great Lakes basin. From an airplane, one can view an entire lake or lake basin. From a canoe, one can view a single turtle. Indicators identified for SOLEC 98 are intended to be generally applicable on a basin-wide or lake basin scale. Lake-by-lake differences may exist in end points or reference values for some indicators, but the indicators themselves should be relevant across lakes. Indicators of local conditions, as might be presented in Remedial Action Plans for Areas of Concern, are not the focus for SOLEC 98. In addition, the indicators identified for SOLEC 98 should reflect changes in conditions in the short, medium, and long-term.

## 2.4 The Need for an Indicator List

One way to determine the status of the health of the Great Lakes ecosystem is to use indicators, which address a spectrum of conditions ranging from the health of humans and

other living components of the system to the stressors and the activities that cause them. Ecosystem health indicators reflect ecosystem quality or trends in quality that are useful to managers and scientists. However, ecosystems are inherently complex so that any single indicator (or even suites of indicators) cannot be completely representative of all possible conditions.

The Parties to the GLWQA want to establish a consistent, easily understood suite of indicators that will objectively represent the state of major ecosystem components across all Great Lakes basins which the Parties can use to report progress every two years. This suite of indicators should also be used to assess the Parties regarding achievement of the purpose of the GLWQA.

The goal of this project is to assemble a basin-wide suite of scientifically valid indicators that will be most useful and understandable in determining and reporting the health of the Great Lakes ecosystem to the interested public.

The SOLEC 98 process will assemble a set of indicators that reflects the state of major ecosystem components for the Great Lakes, including open and nearshore waters, coastal wetlands, nearshore terrestrial environments, human health, stewardship, and socio-economics/land use. The indicators nominated for the SOLEC list were extracted primarily from existing Great Lakes documents (see Appendix 7), (e.g., Lakewide Management Plans, fish community objectives), and proposed indicators of desired outcomes.

## 2.5 Why Should There be Agreement on Indicators?

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 proportional to 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. An understanding by stakeholders about what information is necessary and sufficient to characterize the state of Great Lakes ecosystem health through the use of indicators, and to measure progress toward ecosystem goals, would facilitate efficient monitoring and reporting programs. Common 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.

The International Joint Commission (IJC) has a responsibility to evaluate progress toward achieving the goals and objectives of the GLWQA. A set of indicators that is relevant to both the IJC and the Parties will prevent a dilution of monitoring effort for competing purposes, and

will foster cooperation between the Parties and the IJC for the common good of the Great Lakes ecosystem. Data will be collected for pre-determined applications, and they will be available on a timely basis. This system of a core set of indicators will be flexible enough to expand to take into account new emerging issues.

Access by non-government organizations (NGOs) to environmental data should become easier, and the data should be more timely and more relevant to a wide variety of stakeholders. Results of government programs for environmental protection and restoration (or lack thereof) would be easier to identify.

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. The SOLEC process will not attempt to impose a uniform set of indicators onto all user groups, nor will it discourage new indicator development work. However, the SOLEC Indicators List is expected to influence future monitoring and data gathering efforts for a common broad scale set of indicators. An understanding by multiple stakeholders about what information is necessary and sufficient to characterize the health of the Great Lakes ecosystem should foster cost-efficient, standardized, and relevant monitoring programs.

...the SOLEC Indicators List is expected to influence future monitoring and data gathering efforts...

## 3.0 The Process for Selecting SOLEC Indicators

### 3.1 Pre-SOLEC 98

In preparation for SOLEC 98, a SOLEC Indicators Group was established by the SOLEC Steering Committee and asked to identify a set of indicators that reflects the state of all major Great Lakes ecosystem components. The Indicators Group consisted of volunteers from government, industry, academics, plus contracted writers/coordinators, each an expert in some aspect of the Great Lakes ecosystem. Because of the high degree of interest in this project, representatives from the LaMP work groups, IJC, and other government agencies participated as their time permitted.

The enormous task of finding indicators applicable to the Great Lakes basin ecosystem was originally divided into seven Core Groups, each lead by experts in the respective fields:

- Open waters;
- Nearshore waters;
- Coastal wetlands;
- Nearshore terrestrial (land by the Lakes);
- Human health;
- Socio-economics/Land use; and
- Stewardship

Each of the seven groups proceeded to select a set of indicators for its domain that would be proposed as part of the SOLEC list. The Indicators Group coordinated the work, setting out guidelines for the process (outlined below), arranging conference calls, etc. The groups worked

largely independently, but each group followed a process somewhat similar to that listed below. Alternative and/or additional steps in the process followed by some groups are presented in the specific group sections of this report.

The following is a list of activities that each group undertook to select a list of proposed SOLEC Indicators:

**1. Assembled a group of experts.** Each group identified and invited additional experts to assist in the selection or review of the proposed indicators. Efforts were made to include both Canadian and U.S. representatives on the expert panels, but representation from every agency was not attempted. See Appendix 8 for the list of work group participants.

**2. Reviewed and extracted proposed indicators from Great Lakes documents.** An initial list of 55 documents was identified early in the process, and this list was the starting point for each group. The documents included reports from previous SOLEC conferences, the LaMP work groups, the IJC, the Great Lakes Fishery Commission, the Great Lakes Water Quality Agreement, and others. Each group was also encouraged to find and use other sources for Great Lakes indicators. See Appendix 7 for a full list of documents.

**3. Identified potential indicators from non-Great Lakes documents.** Some groups found that few indicators had been proposed for the Great Lakes for their domain or that other, non-Great Lakes sources provided relevant indicators or approaches. As time permitted or need required, these additional sources were consulted, and indicators not previously proposed for the Great Lakes were identified. Appendix 7 also includes these documents.

**4. Entered information about potential indicators into a database.** A relational database was created specifically to assist the Indicator Group assemble, maintain and sort through the potential indicators for the SOLEC list. Each indicator extracted from (or mined out of) the documents was entered into the electronic database. See Section 3.4 and Appendix 5 for a detailed description of the database, the information retained about each indicator, and its potential usefulness to other user groups. In addition, see Appendix 2 for a full listing of all indicators entered into the database.

**5. Screened the indicators using a broad set of SOLEC criteria.** There were three general criteria that had to be met for an indicator to be put forward as a candidate for a SOLEC indicator:

**Necessary** - Do we really need to monitor a particular indicator? We want to gather information that is necessary to assess ecosystem health.

**Sufficient** - Will the suite of indicators give us enough information to assess the health of the Great Lakes ecosystem? We don't want to make an overall assessment of ecosystem health from too few indicators.

**Feasible** - Can the information reasonably be gathered, considering budgetary and monitoring constraints? The ideal situation would be if a monitoring program is already in place to gather the needed information.

**6. Selected a subset (short list) of indicators from the database to be proposed for the SOLEC Indicators List based on expert opinion.** The groups varied considerably in their approach to this critical task. For some groups (e.g., coastal wetlands, nearshore terrestrial),

an active expert panel reviewed the entire list of indicators related to their domain, provided advice about the selection of an appropriate subset, and/or were involved in the combining or modification of indicators to create a subset more suitable for SOLEC needs. For other groups, the group leaders provided most of the energy for identifying the subset, and the expert panel was consulted during the process or provided review comments. Consultation with the expert panels is expected to continue up to and beyond SOLEC 98.

**7. Screened the short list of indicators with a comprehensive set of SOLEC criteria.** A set of selection criteria were adapted from a recent EPA document, *Process for Selecting Environmental Indicators and Supporting Data*, and modified slightly to better fit this project. These 21 criteria fall under seven categories: validity, understandability, interpretability, information richness, data availability, timeliness, and cost considerations. These criteria will continue to be the basis for the review, selection and refinement of the indicators proposed for the SOLEC list. Reviewers of the SOLEC list have been encouraged to refer to these criteria when suggesting improvements, additions or deletions from the list. These criteria can be found in Appendix 4.

**8. Sent the short list (Version 1) out for review.** During the review process of the selected indicators, stakeholders have been invited to provide advice on what indicators would be useful and interesting - June, 1998

**9. Comments from review considered and revisions made.** A draft report and SOLEC Indicator List (Version 2) were prepared for discussions at SOLEC 98 in October 1998.

**10. Identify ecosystem components for which additional indicator development is needed.** This step has been and will continue to be considered throughout the process.

## 3.2 SOLEC 98

Many discussions about the Indicators List were held at SOLEC 98. The conference workshops looked at the individual core group suites of indicators as well as the total suite of indicators (basin-wide overview). Many comments, concerns, suggestions and plain old-fashioned good advice were garnered from these sessions. A more detailed description of the SOLEC 98 indicator workshops can be found in the "SOLEC 98 Conference Proceedings" document (available on-line at <http://www.cciw.ca/solec/>).

## 3.3 Post-SOLEC 98

The majority of the comments from the SOLEC 98 workshops were thoroughly discussed at a meeting of the core group leaders in January 1999. As a result of these discussions a few indicators were deleted or combined with others, a few new indicators were added and the remainder were revised as appropriate. See Appendix 9 for the current list of the SOLEC indicators.

After the revisions were made, each indicator was subjected to a clarification and consistency check. The purpose of this was to ensure that the indicators are clear and understandable and that they all follow a similar format. This process resulted in a much better indicator descriptor (see Appendix 1) and also helped to identify gaps in information as well as identifying future research needs.

For each indicator, a third party assessment against the SOLEC criteria was also undertaken - the results of which can be seen in Appendix 4.

In addition, and as a result of comments heard at SOLEC 98, the indicators have been categorized in several ways, in order to meet the needs of SOLEC and other interested stakeholders. The indicators can now be sorted and organized for many different means (for example, if you may be interested in seeing a list of all the SOLEC indicators that relate to the GLWQA Annex 12, Persistent Toxic Substances, these can then be sub-categorized by state, pressure, and human activity). For more details on many indicator sorting possibilities please see Appendix 3.

**Version 3 of the *Selection of Indicators for Great Lakes Ecosystem Health* is being distributed for broad review to a wide variety of stakeholders. It will be reviewed from both a technical standpoint and a policy standpoint in the hopes of generating an understanding of the project, as well as getting buy-in and commitment. Comments received from this review will be used to generate the next version of the indicator list and report, which will be appended to the 1999 State of the Great Lakes report. The 1999 State of the Great Lakes report will be released at the end of August 1999.**

### 3.4 The SOLEC Indicators Database

To assist the Indicator Group collect and sort indicators from existing documents, a database was designed to retain two main types of information about each indicator: 1) information useful for sorting the indicators according to various user perspectives, and 2) a detailed description of each indicator. Because the database contains information about indicators, but does not contain any of the environmental measurements, the information is more appropriately described as meta-data.

Within the database, each indicator under consideration for the SOLEC list was designated a "Candidate." After a decision about an indicator has been reached regarding its inclusion on the SOLEC list, its status is changed to "Yes," "No," or "Concept Retained." See Appendix 5 for more details about these designations.

The "sorting" part of the database contains fields whose elements are selected by pull down pick lists. For example, information is stored concerning the indicator source program or group, type of indicator (i.e. state, pressure or human activity), and applicable SOLEC group (i.e. open waters, nearshore waters, coastal wetlands...). Nearly all of the indicators entered into the database are associated with some or all of these fields.

The "description" part of the database contains text fields that provide details about the indicator itself. This information is provided, to the best extent possible, for each of the indicators being proposed to the SOLEC list. For many of the other indicators in the database, this information was either not available or remains within the source documents but was not transferred to the database. The text fields include: indicator purpose, ecosystem objective, indicator features, desired endpoint (or range, outcome or other reference value), indicator limitations, indicator interpretation, and additional comments.

Originally conceived as an organizing and sorting tool for the SOLEC Indicator Group, the database may have value to other user groups. Therefore, an explanation and/or rationale for each of the database fields is provided in Appendix 5. Since SOLEC 98 work has proceeded

on the database to make it more useable to a broader audience as well as making it more user friendly. An interactive version is expected to go on-line by the summer 1999. Please check the SOLEC web sites frequently.

## 4.0 Indicator Core Groups

*Please note: the following sub-sections have been substantially edited for brevity. If you require further details on the process of each core group then please refer to the October 1998 draft of "Selection of Indicators for Great Lakes Basin Ecosystem Health."*

### 4.1 Nearshore and Open Waters

#### Definition of Nearshore and Open Waters

For the purposes of SOLEC 98 the nearshore and open waters are defined as in the SOLEC 96 background paper "Nearshore Waters of the Great Lakes":

*A band of varying width around the perimeter of each lake between the land and deeper offshore waters of the lake. The band begins at the shoreline or the lakeward edge of the coastal wetlands and extends offshore to the deepest lake-bed depth contour at which the thermocline typically intersects with the lake bed in late summer or early fall. Also included as nearshore waters are the Great Lakes connecting channels and the reaches of tributaries that are subject to seiche activity. Offshore Waters, as the name implies, are all of the waters beyond the lakeward edge of the nearshore waters.*

#### Scale

An attempt was made to develop individual indicators that could be used to provide basin-wide status and trend information for the aquatic resources and habitats of the Great Lakes. Whenever possible, reference values have been provided specific to each lake to reflect significant natural differences between lakes, whether those differences occurred historically or are found currently.

#### 4.1.1 The Indicator Selection Process

The Open Waters (OW) and Nearshore Waters (NSW) Core Groups proceeded independently during the initial phases. However, many of the indicators in one group were duplicated by the other. The two groups and their lists were consolidated for reconsideration and elimination of duplicative entries.

The groups' philosophical approach was to present the minimum number of indicators needed to address the important environmental issues of concern. The indicators needed to have solid scientific underpinnings yet be presented in terms that could be easily understood by a non-technical audience.

...present the minimum number of indicators needed to address the important environmental issues...

The candidate indicator list was reduced, and subject experts for each indicator topic were sought. In most cases the experts provided the text for the descriptive information. At SOLEC 98 the Open and Nearshore Waters list contained 19 indicators. Based on comments and suggestions from the conference two indicators were moved to the Coastal Wetlands group, and one composite indicator was split into four separate indicators, for a new total of 20 indicators. The indicators have been revisited by the experts with substantial revisions made to the content.

#### 4.1.2 Problems Encountered

Descriptive information for each indicator has been expanded on since SOLEC 98, but in some cases it is still incomplete. Technical experts who could address the candidate indicators in detail were often difficult to enlist.

#### 4.1.3 Open and Nearshore Waters Indicators

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

##### STATE

###### Aquatic Habitat (Indicator #0006)

This indicator will measure the quality and amount of aquatic habitat in the Great Lakes ecosystem and indirectly measure progress in rehabilitating degraded habitat and associated aquatic communities.

###### Salmon and Trout (Indicator #0008)

This indicator will measure populations of introduced trout and salmon populations and indirectly measure the potential impacts on native trout and salmon populations and the preyfish populations that support them.

###### Walleye and *Hexagenia* (Indicator #0009)

This indicator will measure status and trends in walleye and *Hexagenia* populations, and indirectly assess 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 measure abundance and diversity of preyfish populations and indirectly measure the stability of predator species necessary to maintain the biological integrity of each lake.

###### Native Unionid Mussels (Indicator #0068)

This indicator will measure the population status of native Unionid populations and indirectly measure the impact of the invading Dreissenid mussel on the Unionid mussel.

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

This indicator will measure status and trends in lake trout and *D. hoyi* populations and indirectly measure 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 measure deformities, erosion, lesions and tumors (DELT) index (Ohio EPA) in nearshore fish and indirectly measure degraded habitat within the Great Lakes.

Benthos Diversity and Abundance (Indicator #0104)

This indicator will measure species diversity and abundance in the aquatic oligochaete community and indirectly measure the relative health of the benthic community.

Phytoplankton Populations (Indicator #0109)

This indicator will measure species and size composition of phytoplankton populations in the Great Lakes and indirectly measure the impact of nutrient enrichment, contamination and invasive exotic predators on the Great Lakes ecosystem.

Zooplankton Populations as Indicators of Ecosystem Health (Indicator #0116)

This indicator will measure changes in community composition, mean individual size, biomass and production of zooplankton populations in the Great Lakes basin, and indirectly measure changes in food-web dynamics due to changes in vertebrate or invertebrate predation, and changes in system productivity; the type and intensity of predation; and energy transfer within a system.

**PRESSURE**

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 measure water withdrawal rates at once-through cooling at steam-electric and pumped-storage power plants in the Great Lakes and connecting channels, and indirectly measure site-specific entrainment mortality of fishes by using water withdrawal rates to calculate an annual, aggregated, basin-wide estimate.

Phosphorus Concentrations and Loadings (Indicator #0111)

This indicator will measure total phosphorus levels in the Great Lakes and indirectly measure degradation of the aquatic ecosystem and the loss of beneficial uses and to indirectly measure human-induced causes of phosphorus loadings.

Contaminants in Recreational Fish (Indicator #0113)

This indicator will measure levels of PBT chemicals in fish and indirectly measure the potential harm to human health through consumption of contaminated fish.

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

This indicator will measure levels of PBT chemicals in young-of-the-year spottail shiners and indirectly measure potential harm to fish-eating wildlife.

Contaminants in Colonial Nesting Waterbirds (Indicator #0115)

To directly measure chemical concentration levels in colonial waterbirds and to indirectly measure the impact of these contaminants on the colonial waterbird population and other aquatic wildlife.

#### Atmospheric Deposition of Toxic Chemicals (Indicator #0117)

This indicator will measure the annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes and indirectly measure potential impacts of toxic chemicals from atmospheric deposition on human health and the Great Lakes aquatic ecosystem, as well as indirectly measure 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 measure the concentration of priority toxic chemicals in offshore waters and indirectly measure the potential impacts of toxic chemicals on human health and the Great Lakes aquatic ecosystem, as well as indirectly measure 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 measure concentrations of IJC priority toxic chemicals in sediments and indirectly measure potential harm to aquatic ecosystems by contaminated sediments, as well as indirectly measure 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 measure loadings of IJC priority pollutants to the Great Lakes and indirectly measure the potential harm these contaminants pose to human, animal and aquatic life within the Great Lakes, as well as indirectly measure the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

## 4.2 Coastal Wetlands

### Coastal Wetlands Definition

The extent of Great Lakes coastal wetlands fluctuates greatly with natural lake processes which can particularly affect the lake-side boundary. For SOLEC, the inland boundary is the extent of wetlands as far as the 100-year floodline of the Lakes (as described in the SOLEC 96 background paper “Coastal Wetlands of the Great Lakes”).

Coastal wetlands differ from inland wetlands in that they are shaped by large-lake processes, including waves, wind tides, seiches, and especially seasonal and long-term fluctuations in water levels. They include emergent marshes, strand communities, wet meadows, submergent communities, swamps, and peatlands. They occur in a number of geomorphological settings: open shoreline, unrestricted bays, shallow sloping beaches, river deltas, restricted riverine settings, Lake-connected inlands, barrier beaches, and diked wetlands. The SOLEC 96 background paper “Coastal Wetlands of the Great Lakes” provides a detailed description of the types of coastal wetlands and the geomorphological settings in which they occur.

### Indicating Health and Integrity

To select indicators of the health and integrity of coastal wetlands, the following definition of coastal wetland health was used:

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

## **Scale**

For the purpose of SOLEC 98, the recommended indicators should be basin-wide. The IJC suggests an understanding of a system at any scale requires indicators of at least three scales: a) the level in question; b) the level above for context; and c) the level below for mechanisms. In the case of coastal wetland indicators we are considering indicators at the following scales: individual Lake basins, the Great Lakes basin, and a set of sites. Monitoring at sites will require a choice of representative sites.

## **Representative Wetland Sites**

Representative sites have yet to be chosen for monitoring the recommended indicators. Ideally, sites should represent wetland distribution among the Lakes, and take into account influencing pressures, wetland types, and geomorphological settings. In part the selection will be based on the representative reaches identified through the “Coastal Wetlands Biodiversity Investment Areas” paper. They should also include high quality (i.e., relatively pristine) reference sites to serve as baselines for comparison to the more degraded sites. It should be recognized, of course, that some parts of the Great Lakes basin no longer have any reference sites of this quality, and reference sites themselves will be degraded to some degree. This is particularly true of Lake Ontario, which has had regulated water levels for about 40 years.

### **4.2.1 The Indicator Selection Process**

Potential coastal wetlands indicators were “mined” from eleven documents. Reviewing the documents and listing information for indicators related to wetland health yielded 330 potential indicators for further consideration. These were grouped into eleven categories: Area, Habitat, Vegetation, Community/Diversity, Benthos, Fish, Contaminants, Nutrients, Human/Land Use/Terrestrial, Species, and Physical Factor in order to identify and remove duplication.

Based on the SOLEC criteria (Appendix 4), the indicators were ranked by the Coastal Wetlands expert panel and those that ranked low were no longer considered. The expert panel made recommendations of the best indicators, but in some cases additional indicators were suggested.

Because SOLEC primarily focuses on pressures and the state of the ecosystem, and does not make recommendations on programs, the coastal wetlands group did not recommend human activities indicators. The list was further refined and revised so that there were 15 recommended indicators in the coastal wetlands suite for SOLEC 98. However, since the conference, a few indicators have been moved into the coastal wetlands suite, some have been deleted and some have been combined with others, so that there are now 13 indicators in the coastal wetlands suite.

### **4.2.2 Problems / Unresolved Issues**

#### **Difficulties Encountered with the Process**

For SOLEC purposes, indicators need to have specific measures that can either utilize data being provided by an existing monitoring program or provide sufficient detail that a new monitoring program can be designed. However, few of the documents contained any significant information beyond the name of the indicator, and most of the indicator names were vague (e.g., quantity and quality of wetlands).

However, indicators clearly could not have been developed without first reviewing what others had done. With the indicators grouped into broad classes, they could be easily compared, modified, or combined. Thus, the process involved an additional step, but produced a proposed suite of indicators that the coastal wetlands group feels will allow an adequate assessment of the ecological health of Great Lakes coastal wetlands.

### Unresolved Issues

Protocols for monitoring several of the indicators still need to be refined. The wide natural fluctuations associated with many features of Great Lakes coastal wetlands complicate the setting of desired endpoints. Some may require modifications. The method to select representative sites for monitoring also needs refinement.

The segregation of coastal wetlands from the other groups was necessary for a manageable process. This organization, however, hindered some broader ecosystem considerations. Positioned between the lakes and upland, and affected by processes in each, healthy coastal wetlands depend on healthy lake and watershed ecosystems. As such, coastal wetlands could be considered indicators of the health of the whole basin ecosystem (and so all that would be needed); or conversely, the health of the Land Use, Nearshore Terrestrial and Open and Nearshore Waters could indicate coastal wetland health (and wetland indicators would not be needed). These links and their implications for what is necessary and sufficient could not be explored.

In general, if there is broad agreement among the Great Lakes constituency on SOLEC indicators for coastal wetlands, organizations at all levels may be responsive to sharing monitoring expertise among themselves without any one organization taking an undue burden.

There are few existing monitoring programs for Great Lakes coastal wetlands. Efforts were made in the coastal wetlands group to select indicators for which there are existing data and monitoring programs, particularly for the pressure indicators. Many of the indicators will require new or improved monitoring programs. For the new programs to attain SOLEC's feasibility criterion, it is suggested that:

- C Monitoring be conducted by volunteers, where possible. Volunteers would require training and adherence to monitoring protocols and quality assurance plans; however, this is true for professionals as well.
- C Monitoring frequencies for each indicator will also need to be determined. While some indicators may need to be monitored several times a year, the more intensive (and expensive) monitoring may only need to be conducted every few years.
- C Different organizations may be able to incorporate new protocols into their ongoing monitoring programs, without an inordinate increase in costs.

### **4.2.3 Coastal Wetland Indicators**

#### **STATE**

Coastal Wetland Invertebrate Community Health (Indicator #4501)

This indicator will measure the diversity of the invertebrate community, especially aquatic insects, and indirectly measure habitat suitability and biological integrity of Great Lakes coastal wetlands.

Coastal Wetland Fish Community Health (Indicator #4502)

This indicator will measure fish community diversity and indirectly measure habitat suitability for Great Lakes coastal wetland fish communities.

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

This indicator will measure the incidence of DELT in fish of Great Lakes coastal wetlands and to indirectly measure the ecosystem health of Great Lakes coastal wetlands.

Amphibian Diversity and Abundance (Indicator #4504)

This indicator will measure the species composition and relative abundance of frogs and toads and indirectly measure 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 measure the wetland bird species composition and relative abundance and indirectly measure 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)

To measure 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)

To measure the gain in restored wetland area and the success of conservation / rehabilitation efforts.

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

To measure the decline of vegetative diversity as characterized by the increase in the presence, abundance, and expansion of invasive plants and to provide a surrogate measure of coastal wetland quality because the presence of invasive plant species generally indicates the level of coastal manipulation or input of sediments which cause wetland degradation.

Habitat Adjacent to Coastal Wetlands (Indicator #7055)

This indicator will measure 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**

Contaminants in Snapping Turtle Eggs (Indicator #4506)

This indicator will measure the accumulation of organochlorine chemicals and mercury in Snapping Turtle eggs and indirectly measure the concentrations, as well as identify

the source, of organochlorine chemicals and mercury in food webs of Great Lakes coastal wetlands.

#### Sediment Flowing into Coastal Wetlands (Indicator #4516)

To indicate sediment load to coastal wetlands and its potential impact on wetland health.

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

This indicator will measure the amount of nitrate and total phosphorus affecting Great Lakes coastal wetlands and indirectly measure the human influence on nutrient levels, as excess nutrients can be detrimental to the health of coastal wetlands.

#### Water Level Fluctuations (Indicator #4861)

This indicator will measure lake level trends that may significantly affect components of wetland ecosystems, and indirectly measure the effect of water level regulation on emergent wetland extent.

### **4.3 Nearshore Terrestrial**

#### **4.3.1 The Indicator Selection Process**

A process similar to the Coastal Wetlands group was followed to develop a proposed set of indicators of the health of the nearshore environment.

First, potential indicators were mined from reports and documents, most of which related to the Great Lakes, but a reports few had broader applications (see Appendix 7). With the help of an expert panel the initial list of 145 indicators was winnowed down by assessing against the basic criteria (necessary, sufficient and feasible), removing duplication, and combining or creating new indicators where necessary. This reduced the list quite considerably. Then each of the potential nearshore terrestrial indicators was described more fully. Sixteen indicators for the nearshore terrestrial ecosystem and 3 basin-wide indicators were presented at SOLEC 98. Since the conference, the nearshore terrestrial core group has revised many of the indicators and has worked quite closely with most of the other core groups in order to integrate and reduce duplication of indicators. Twelve indicators remain in the nearshore terrestrial suite, and the identified basin-wide indicators have been integrated into the Land Use group.

#### **The Indicator Framework**

Indicators are provided to highlight physical, biological, and chemical stressors. Within the state categories, indicators are proposed both for habitat status, and for the health and stability of ecological communities/species. Human activities (responses) consider direct actions, such as recovery plans written or habitats protected.

## Issues and Next Steps

A protocol will need to be developed for each of the selected indicators which will establish such details as:

- whether monitoring should take place across the entire nearshore area or in “sentinal sites” only;
- whether indicator results should be reported as trends over time, or in comparison to historical conditions or a defined target (such as RAP habitat targets);
- the degree to which existing monitoring programs and databases can be adapted to each indicator.

### 4.3.2 Nearshore Terrestrial Indicators (within 1 kilometer of shore)

#### STATE

##### ***Indicators related to habitats:***

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

This indicator will measure the amount of natural land cover that falls within 1 km of the shoreline and indirectly measure the impact of artificial coastal structures and primary/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 measure changes in area and quality of the twelve special lakeshore communities and indirectly identify the sources of threats to some of the most ecologically significant habitats in the Great Lakes terrestrial nearshore, as well as indirectly measure the success of management activities associated with the protection status.

Nearshore Species Diversity and Stability  
(Indicator #8137)

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

For the purposes of applying these indicators, the nearshore terrestrial environment was defined as those lands within approximately one kilometer of the Great Lakes shoreline.

#### PRESSURE

##### ***Indicators related to physical stressors:***

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

This indicator will measure lake level trends that may significantly affect components of wetland ecosystems, and indirectly measure the effect of water level regulation on emergent wetland extent.

Extent of Hardened Shoreline (Indicator #8131)

This indicator will measure the amount of shoreline habitat altered by the construction of shore protection, and indirectly measure the potential harm to aquatic life in the nearshore as a result of conditions (i.e., shoreline erosion) created by habitat alteration.

#### Nearshore Land Use Intensity (Indicator #8132)

This indicator will measure the types and extent of major land uses and indirectly measure the effects of land use on significant natural features or processes, particularly on the twelve special lakeshore communities as defined in "Land by the Lakes," a paper from the SOLEC '96.

#### Artificial Coastal Structures (Indicator #8146)

This indicator will measure the number of artificial coastal structures on the Great Lakes and indirectly measure potential harm to coastal habitat by sand transport disruption.

#### ***Indicators related to biological stressors:***

##### Nearshore Plant and Wildlife Problem Species (Indicator #8134)

This indicator will measure the type and abundance of plant and wildlife problem species in landscapes bordering the Great Lakes and indirectly measure the potential threat to the health of nearshore ecological processes and communities.

#### ***Indicators related to chemical stressors:***

##### Contaminants Affecting Productivity of Bald Eagles (Indicator #8135)

This indicator will measure the concentrations of organic and heavy metal contamination in Bald Eagle eggs, blood, and feathers and indirectly measure the concentrations, as well as identify the source, of these contaminants in the food web. Also, it will directly measure injury to wildlife from organic and heavy metal contaminants, and provide an indirect measure of the potential harm to human health through the consumption of contaminated fish.

##### Contaminants Affecting the American Otter (Indicator #8147)

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

### **HUMAN ACTIVITIES (RESPONSE)**

#### Community / Species Plans (Indicator #8139)

This indicator will measure the number of plans that are needed, developed, and implemented to maintain or restore high quality, natural nearshore communities and federally / nationally listed endangered, threatened, and vulnerable species, and will measure the type and number of communities and species that require protection. This indicator will also indirectly measure the type and number of communities that will potentially be maintained / recovered through plan development and implementation.

#### Shoreline Management Under Integrated Management Plans (Indicator #8141)

This indicator will measure the amount of Great Lakes shoreline managed under an integrated management plan, and indirectly measure the degree of stewardship of shoreline processes and habitat.

#### Nearshore Protected Areas (Indicator #8149)

This indicator will measure the kilometers/miles of shoreline in protective status and the kind of protection in place and indirectly measure 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 links in the migration (lifecycle) of birds and butterflies which migrate continentally.

## 4.5 Land Use

### 4.5.1 The Indicator Selection Process

Poor land use by humans is the predominant cause of environmental problems in the ecosystems of the Great Lakes basin. In spite of considerable evidence of the significant disadvantages of urban sprawl, this development form continues to be the most commonly applied approach to new development. Clearly, as was concluded in SOLEC 96, there is a need for better ways of influencing decision-makers in the Great Lakes basin to make environmentally informed development decisions. The land use indicators are intended to meet that need.

Poor land use is a major source of environmental stress in the Great Lakes basin ecosystem.

Several documents and reports were consulted to develop an initial list of Land Use indicators (see Appendix 7). Using the basic criteria of necessary, sufficient and feasible, the list was then shortened. An expert panel was formed to review, revise and add further detail to these indicators. Sixteen Land Use indicators were presented at SOLEC 98. This group generated a lot of interest at the conference and substantial comments and suggestions were made. In response to this, the two societal indicators have been moved to the new Societal core group. The remaining Land Use indicators have undergone major revisions - some have been deleted, some split into two or more indicators, and indicators from other core groups have been added to the Land Use group. Fourteen indicators remain in the Land Use core group.

### 4.5.2 Land Use Indicators

#### STATE

Breeding Bird Diversity and Abundance (Indicator #8150)

This indicator will measure the status of breeding bird populations and communities and indirectly measure the health of breeding bird habitat in the Great Lakes basin.

Threatened Species (Indicator #8161)

This indicator will measure the number, extent and viability of threatened species, key components of biodiversity in the Great Lakes basin, and indirectly measure the ecological integrity of processes and systems (e.g., sand accretion, hydrologic regime) within Great Lakes habitats.

#### PRESSURE

Urban Density (Indicator #7000)

This indicator will measure human population density and indirectly measure the degree of inefficient land use and urban sprawl for communities in the Great Lakes ecosystem.

#### Land Conversion (Indicator #7002)

This indicator will measure changes in land use within the Great Lakes basin and indirectly measure the potential impact of land conversion on Great Lakes ecosystem health.

#### Mass Transportation (Indicator #7012)

This indicator will measure the percentage of commuters using public transportation and indirectly measure 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 measure the amount and distribution of natural habitat remaining within Great Lakes ecoregions and indirectly measure 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 measure the amount of water entering the Great Lakes through major tributaries and connecting channels, and indirectly measure the amount of sediment available for transport to nourish coastal ecosystems.

### **HUMAN ACTIVITIES (Response)**

#### Brownfield Redevelopment (Indicator #7006)

This indicator will measure the acreage of redeveloped brownfields and indirectly measure the rate at which society responds to the opportunity to rehabilitate and reuse former developed land sites that have been degraded by poor use.

#### Use of Sustainable Agriculture Practices (Indicator #7028)

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

#### Green Planning Process (Indicator #7053)

This indicator will measure the number of municipalities with environmental and resource conservation management plans in place and indirectly measure 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 measure the amount of water used in the Great Lakes basin and indirectly measure the amount of wastewater generated and the demand for resources to pump and treat water.

#### Energy Consumption (Indicator #7057)

This indicator will measure the amount of energy consumed in the Great Lakes basin and indirectly measure the demand for resources from the ecosystem, as well as the levels of pollution and other associated negative impacts on the ecosystem. Energy

consumption is a good proxy for resource use, waste and pollution creation, and ecosystem stress.

#### Wastewater Pollution (Indicator #7059)

This indicator will measure loadings of wastewater pollutants discharged into the Great Lakes basin and indirectly measure 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 measure the amount of solid waste generated per capita per capita in the Great Lakes basin and indirectly measure inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

## 4.4 Human Health

### 4.4.1 The Indicator Selection Process

There is interest in having indices or indicators for monitoring progress or changes in human health as it relates to the Great Lakes environment. These can be either changes over time or comparisons between geographic regions. The premise is that as environmental conditions change in the Great Lakes basin, so does the state of the health of the population in that region. Such indicators are also needed to assess the effectiveness of health and environment policies and actions in protecting or improving the health of the Great Lakes basin population.

With our present knowledge, it is clear that no single indicator is adequate to establish associations and trends between human health and the environment. Consequently, indicators were chosen which, as a whole, serve to monitor human health as it relates to the Great Lakes environment. The indicators chosen are by no means exhaustive but represent an initial effort at establishing health-related indicators for the Great Lakes population. As research progresses in this area, other indicators can be added to the current suite of indicators, or may replace them altogether.

...it is clear that no single indicator is adequate to establish associations and trends between human health and the environment.

For practical purposes, this effort to develop health indicators for SOLEC has focused primarily on indicators of human exposure to environmental contaminants along with some geographic patterns and trends in disease incidence. 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, 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, the analysis of 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 extensive initial list of indicators identified by the Human Health Core Group was reduced by eliminating those indicators that were thought not to be informative, either because 1)

specific exposure media were unlikely to make a relatively significant contribution to overall contamination exposure levels, 2) some contaminants were unlikely to be detected in specific media, or 3) difficulties in obtaining information in a comprehensive manner. A greater weight was given to those indicators that represented data available from current monitoring programs, to those indicators that were supported by an existing database, and to those indicators that were more likely to provide information that could be used to evaluate the relationships between contaminant exposures and health. The final eight indicators have been revised, based on comments and suggestions given at the SOLEC 98 workshops.

Although there exist many other indicators of health such as life expectancy, birth weight and well being, these were not included in the final list because the impact of current environmental conditions on these indicators is either not well understood or not well developed. In many cases, improvements in these indicators have occurred even during times of changing environmental quality due to population growth and industrialization in the Great Lakes basin. Advances in public health, medicine, access to health care, education, and economy contributed greatly to improvements in the health of the population. However, as we gain more information on the relationships between these parameters and the environment, their inclusion as future indicators may be warranted.

#### **4.4.2 Human Health Indicators**

##### **STATE**

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

This indicator will measure the disease incidences in the Great Lakes basin population and also will assess areas in the Great Lakes basin where further investigation of the exposure and effects of environmental pollutants on human health is needed.

##### **PRESSURE (Indicators of Exposure)**

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

This indicator will measure coliform contaminant levels in nearshore recreational waters, and act as a surrogate indicator for other pathogen types, to indirectly measure potential harm to human health through body contact with nearshore recreational waters.

Chemical Contaminants in Fish Tissue (Indicator #4083)

This indicator will measure the concentration of PBT chemicals in Great Lakes fish and indirectly measure the 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 indirectly estimate 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 measure chemical and microbial contaminant levels in drinking water and indirectly measure potential for human exposure to drinking water contaminants, as well as indirectly measure 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 indirectly measure the potential impact of air quality on human health in the Great Lakes basin.

#### Chemical Contaminants in Human Tissue (Indicator #4177)

This indicator will measure the concentration of PBT chemicals in human tissues and indirectly measure the efficacy of policies and technology to reduce PBT chemicals in the Great Lakes ecosystem.

#### Radionuclides (Indicator #4178)

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

## 4.6 Societal

In the period between SOLEC 98 and Spring 1999 the decision was made to broaden the scope of the Stewardship Core Group to include socio-economic and other societal indicators. Since this group now housed the indicators of society, it was renamed "Societal" in order to reflect this change. In the future, it is hoped that an indicator of social well-being will also be included in this group.

### 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. Thus, *sustainability* is the expression of the overall "desirable end state" and *ecosystem management* describes the basic strategy employed in *the process of stewardship*.

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

...stewardship activities are intended to achieve a sustainable future — a balance between environmental integrity, economic viability, and social well-being.

The initial process to identify indicators of stewardship for SOLEC 98 was similar to that for the other groups, but with inconclusive results. Few documents were found that contained indicators for stewardship in the Great Lakes. Although many ideas had been generated, there were very few appropriate stewardship indicators, and they were quite general.

The approach described in Section 4.6.1 was developed just prior to SOLEC 98. Due to the late change in emphasis, **neither the approach nor the proposed indicators had received extensive review from an expert panel or other stakeholders prior to SOLEC 98. In the period since SOLEC 98, the Stewardship indicators have had little additional attention. Suggestions for improving this approach and for identifying SOLEC stewardship indicators are welcomed and encouraged.**

### **Socio-Economics and Other Aspects of Society**

The health of the environment is closely tied to a regions' economy and societal values. In the case of 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.

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 callous creation and discharge of waste materials may impact on the habitat of other species, result in contamination and other health problems. From an aesthetic viewpoint, trash is easily noticed and offensive to a well developed and organized society.

#### **4.6.1 The Indicator Selection Process**

This approach assumes that the existence of these partnerships, their coverage of the Great Lakes basin, their organizational capacities, and the "richness" of their memberships, will lead to improvements in the state of the environment and to reductions of environmental pressures or threats. In addition, local partnerships are framed and supported by citizen interest and involvement in stewardship initiatives, as well as governmental adoption and endorsement of ecosystem management and sustainability principles. These proposed stewardship indicators would track the development and capacities of partnerships engaged in ecosystem management activities in the Great Lakes basin, but not the underlying motivations or other reasons for actions and responses, nor the actual environmental changes brought about by these actions.

### **Socio-Economic and Other Society Indicators**

Some of the indicators (such as economic prosperity, dollars allocated to Great Lakes programs and societal values (like aesthetics)) did not fit very well in their original core group. It was recognized that these indicators should be retained in the suite of Great Lakes basin ecosystem health indicators. This resulted in the expansion of the Stewardship group to a Societal group. The socio-economic section of the suite of Great Lakes indicators is in the early stages of development and further work is needed. It is hoped that in the future an indicator for social well being can be included here.

## 4.6.2 Societal Indicators

### STATE

#### Aesthetics (Indicator #7042)

This indicator will measure the amount of waste and decay around human activities in the Great Lakes basin and indirectly measure 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 measure unemployment rates within the Great Lakes basin and indirectly measure the capacity of the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem.

### HUMAN ACTIVITIES (Response)

#### Capacities of Sustainable Landscape Partnerships (Indicator #3509) - *unchanged from SOLEC 98*

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) - *unchanged from SOLEC 98*

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) - *unchanged from SOLEC 98*

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) - *unchanged from SOLEC 98*

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) - *unchanged from SOLEC 98*

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 measure the amount of dollars spent annually on Great Lakes programs and indirectly measure the responsiveness of Great Lakes programs by

determining the adequacy of annual funding focused on research, monitoring, restoration, and protection of Great Lakes ecosystems by federal and state/provincial agencies and non-governmental organizations.

## 4.7 Unbounded Indicators

Several proposed indicators do not fit neatly into any of the seven SOLEC ecological categories (open waters, nearshore waters, coastal wetlands, nearshore terrestrial, land use, human health, and societal). These categories were selected to be consistent with the themes and papers of the two previous SOLECs, and they provide an organizing framework for selecting and reviewing indicators. The indicators could have been organized differently (for example, “fish, fauna, flora, water, land, air” - and, in fact, they have been sorted this way in Appendix 3 (Relevancies)), however, it is likely that some indicators would still transcend the group boundaries. For example, indicators related to issues such as climate change will affect all the groups yet truly belong in none of them.

Throughout the selection process these indicators were recognized and discussed. In some cases they were kept with the Core Group that originally nominated them, but in other cases they were transferred to another group that appeared to be more relevant. The Indicators Group avoided the creation of the category “miscellaneous” so that each indicator would receive the attention of at least one group, and none would become orphans.

However, for clarity of organization and presentation of the proposed indicators, the creation of an additional category called “Unbounded” was found to be useful. These indicators may have application to more than one of the organizing categories, or they may reflect issues that affect the Great Lakes but have global origins or implications.

**Reviewers please note that the indicators in the Unbounded group have yet to receive an intensive review. We welcome your comments and suggested improvements for these indicators.**

### STATE

Atmospheric Visibility (Indicator #9001)

This indicator will measure the percentage of daylight hours with reduced visibility per year and indirectly measure the efficacy of policies and technologies developed to improve visibility in the Great Lakes basin.

### PRESSURE

Acid Rain (Indicator #9000)

This indicator will measure pH levels in precipitation and critical loadings of sulphate to the Great Lakes basin, and indirectly measure the potential stress to the Great Lakes ecosystem due to acid rain, as well as to indirectly measure the efficacy of policies to reduce sulphur and nitrogen acidic compounds.

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

This indicator will measure the number “extreme storms” each year and indirectly measure the impact of climate change on ecological components of coastal wetlands.



Global Warming: First Emergence of Water Lilies in Coastal Wetlands (Indicator #4857)  
This indicator will measure change in first emergence dates of water lilies as an indicator of climate change affecting wetlands.

Global Warming: Ice Duration on the Great Lakes (Indicator #4858)  
This indicator will measure temperature and accompanying physical changes to each lake and indirectly measure the impact of climate change on wetlands.

# Appendix 1 — Descriptor Information for Each Entry in the SOLEC Indicator List

The following pages include more detailed information on each of the proposed indicators.

## Listing of Indicators

| Indicator Code                   | Indicator Name   | Page |
|----------------------------------|--|------|
| <b>Nearshore and Open Waters</b> |  |      |
| 6                                | Aquatic Habitat  | 1-4  |
| 8                                | Salmon and Trout   | 1-6  |
| 9                                | Walleye and <i>Hexagenia</i>   | 1-8  |
| 17                               | Preyfish Populations   | 1-10 |
| 18                               | Sea Lamprey  | 1-12 |
| 68                               | Native Unionid Mussels   | 1-14 |
| 72                               | Fish Entrainment   | 1-16 |
| 93                               | Lake Trout and Scud ( <i>Diporeia hoyi</i> )                             | 1-18 |
| 101                              | Deformities, Erosion, Lesions and Tumors in Nearshore Fish               | 1-20 |
| 104                              | Benthos Diversity and Abundance  | 1-22 |
| 109                              | Phytoplankton Populations  | 1-23 |
| 111                              | Phosphorus Concentrations and Loadings                                   | 1-25 |
| 113                              | Contaminants in Recreational Fish  | 1-26 |
| 114                              | Contaminants in Young-of-the-Year Spottail Shiners                       | 1-27 |
| 115                              | Contaminants in Colonial Nesting Waterbirds                              | 1-28 |
| 116                              | Zooplankton Populations as Indicators of Ecosystem Health                | 1-30 |
| 117                              | Atmospheric Deposition of Toxic Chemicals                                | 1-32 |
| 118                              | Toxic Chemical Concentrations in Offshore Waters                         | 1-35 |
| 119                              | Concentrations of Contaminants in Sediment Cores                         | 1-36 |
| 120                              | Contaminant Exchanges Between Media: Air to Water, and Water to Sediment | 1-38 |
| <b>Coastal Wetlands</b>          |  |      |
| 4501                             | Coastal Wetland Invertebrate Community Health                            | 1-40 |
| 4502                             | Coastal Wetland Fish Community Health                                    | 1-42 |
| 4503                             | Deformities/Eroded Fins/Lesions/Tumors (DELT) in Coastal Wetland Fish    | 1-43 |
| 4504                             | Amphibian Diversity and Abundance  | 1-44 |
| 4506                             | Contaminants in Snapping Turtle Eggs                                     | 1-46 |
| 4507                             | Wetland-Dependent Bird Diversity and Abundance                           | 1-48 |

| <b>Indicator Code</b>        | <b>Indicator Name</b>  | <b>Page</b> |
|------------------------------|--|-------------|
| 4510                         | Coastal Wetland Area by Type                                   | 1-50        |
| 4511                         | Gain in Restored Coastal Wetland Area by Type                  | 1-51        |
| 4513                         | Presence, Abundance & Expansion of Invasive Plants             | 1-53        |
| 4516                         | Sediment Flowing Into Coastal Wetlands                         | 1-54        |
| 4860                         | Nitrates and Total Phosphorus Into Coastal Wetlands            | 1-55        |
| 4861                         | Water Level Fluctuations                                       | 1-57        |
| 7055                         | Habitat Adjacent to Coastal Wetlands                           | 1-59        |
| <b>Nearshore Terrestrial</b> |  |             |
| 4861                         | Water Level Fluctuations                                       | 1-57        |
| 8129                         | Area, Quality, and Protection of Special Lakeshore Communities | 1-61        |
| 8131                         | Extent of Hardened Shoreline                                   | 1-63        |
| 8132                         | Nearshore Land Use Intensity                                   | 1-64        |
| 8134                         | Nearshore Plant and Wildlife Problem Species                   | 1-66        |
| 8135                         | Contaminants Affecting Productivity of Bald Eagles             | 1-68        |
| 8136                         | Extent and Quality of Nearshore Natural Land Cover             | 1-69        |
| 8137                         | Nearshore Species Diversity and Stability                      | 1-71        |
| 8139                         | Community / Species Plans                                      | 1-73        |
| 8141                         | Shoreline Managed Under Integrated Management Plans            | 1-74        |
| 8146                         | Artificial Coastal Structures                                  | 1-75        |
| 8147                         | Contaminants Affecting the American Otter                      | 1-76        |
| 8149                         | Nearshore Protected Areas                                      | 1-78        |
| <b>Land Use</b>              |  |             |
| 7000                         | Urban Density  | 1-80        |
| 7002                         | Land Conversion  | 1-81        |
| 7006                         | Brownfield Redevelopment                                       | 1-82        |
| 7012                         | Transportation Efficiency                                      | 1-83        |
| 7028                         | Sustainable Agricultural Practices                             | 1-85        |
| 7053                         | Green Planning Process   | 1-86        |
| 7056                         | Water Consumption  | 1-87        |
| 7057                         | Energy Consumption   | 1-88        |
| 7059                         | Waste Water Pollutant Loading                                  | 1-89        |
| 7060                         | Solid Waste Generation   | 1-90        |
| 8114                         | Habitat Fragmentation  | 1-91        |
| 8142                         | Streamflow   | 1-92        |
| 8150                         | Breeding Bird Diversity and Abundance                          | 1-93        |

| <b>Indicator Code</b>      | <b>Indicator Name</b>   | <b>Page</b> |
|----------------------------|---|-------------|
| 8161                       | Threatened Species  | 1-95        |
| <b>Human Health</b>        |   |             |
| 4081                       | Fecal Pollution Levels of Nearshore Recreational Waters             | 1-97        |
| 4083                       | Chemical Contaminants in Fish Tissue                                | 1-98        |
| 4088                       | Chemical Contaminant Intake From Air, Water, Soil and Food          | 1-99        |
| 4175                       | Drinking Water Quality  | 1-100       |
| 4176                       | Air Quality   | 1-101       |
| 4177                       | Chemical Contaminants in Human Tissue                               | 1-103       |
| 4178                       | Radionuclides   | 1-104       |
| 4179                       | Geographic Patterns and Trends in Disease Incidence                 | 1-106       |
| <b>Societal Indicators</b> |   |             |
| 3509                       | Capacities of Sustainable Landscape Partnerships                    | 1-107       |
| 3510                       | Organizational Richness of Sustainable Landscape Partnerships       | 1-108       |
| 3511                       | Integration of Ecosystem Management Principles Across Landscapes    | 1-109       |
| 3512                       | Integration of Sustainability Principles Across Landscapes          | 1-110       |
| 3513                       | Citizen / Community Place-Based Stewardship Activities              | 1-111       |
| 7042                       | Aesthetics  | 1-112       |
| 7043                       | Economic Prosperity   | 1-113       |
| 8140                       | Financial Resources Allocated to Great Lakes Programs               | 1-114       |
| <b>Unbounded</b>           |   |             |
| 4519                       | Global Warming: Number of Extreme Storms                            | 1-116       |
| 4857                       | Global Warming: First Emergence of Water Lilies in Coastal Wetlands | 1-118       |
| 4858                       | Global Warming: Ice Duration on the Great Lakes                     | 1-119       |
| 9000                       | Acid Rain   | 1-121       |
| 9001                       | Atmospheric Visibility: Prevention of Significant Deterioration     | 1-122       |

## **Aquatic Habitat**

### **Indicator ID: 6**

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#### ***Measure***

1) Quality and area of aquatic habitat (e.g., shore, spawning shoals, tributaries, wetlands, etc.) and 2) population of sentinel fish species. For example, the measures for tributary quality could include the number of dams, number of miles of river channel that is impounded, number of miles of (formerly) high-gradient stream channel that is impounded, and the number of miles between the river mouth and the first dam. The number and location of fish passage facilities (up- and downstream) that could be used successfully by species or communities of concern (for example, lake sturgeon, or other anadromous fishes listed in FCGO) could also serve as measures.

#### ***Purpose***

To directly measure the quality and amount of aquatic habitat in the Great Lakes ecosystem and to indirectly measure progress in rehabilitating degraded habitat and associated aquatic communities.

#### ***Ecosystem Objective***

This indicator addresses the general FCGO to protect and enhance fish habitat, achieve no net loss of the productive capacity of habitat supporting fish communities, and restore damaged habitats. Annex 2 of the 1987 Protocol to the Great Lakes Water Quality Agreement calls for the restoration of lost or damaged habitat. The indicator also supports the policy position of the Great Lakes Fishery Commission, Habitat Advisory Board, presented in their 1998 Draft Binational Policy and Action Plan for the Protection and Enhancement of Aquatic Habitat in the Great Lakes.

#### ***Endpoint***

The end points will need to be specific to habitat types and FCGO. In the Great Lakes and connecting channels, for example, the U.S. Environmental Protection Agency and Ontario Ministry of the Environment numerical guidelines for dumping of contaminated dredged sediments can be used to protect aquatic habitat quality.

#### ***Features***

This indicator will measure/calculate changes in aquatic habitat by area, by type, by location, by Lake, and by Biodiversity Investment Areas as classified by the Biodiversity Investment Area Nearshore Terrestrial Ecosystems paper from SOLEC '96. Significant losses and degradation of aquatic habitat have occurred in the Great Lakes aquatic ecosystem since the late 1800s when European settlement of the region was completed. Logging, navigation projects, dam construction, shoreline development, agriculture, urbanization, and municipal and industrial waste disposal have all acted to reduce the amount and quality of aquatic habitat in the system. These affected habitats include the Great Lakes proper, their connecting channels and coastal wetlands, and the tributaries that provide linkages with inland aquatic habitats and terrestrial habitats via the surface water continuum. Each of these aquatic habitat types supports one or more aquatic communities. Wetland losses in the region have been reasonably well documented and quantified, but losses of the other major habitat types have not. Recent efforts to relicense hydropower dams in the United States have led to a reconsideration of the habitat losses associated with these dams and a useful picture is emerging which allows an assessment of the adverse impacts of habitat fragmentation on anadromous and resident stream-fish communities. Data for tributary habitat are being developed in connection with FERC dam relicensing procedures in the United States. Data are presently available for Michigan, New York State, and Wisconsin.

#### ***Illustration***

#### ***Limitations***

Restoration ecology is an emerging scientific discipline requiring an understanding of multiple disciplines and partnerships. Comprehensive, detailed habitat inventory, classification, and mapping of Great Lakes aquatic habitats has not been undertaken.

#### ***Interpretation***

Dam removal, switching from peak-power generating flow mode to run-of-the-river flow mode, and provision of fully functional upstream and downstream fish passage facilities consistent with state management strategies or FCGO would be considered to be rehabilitation of habitat and beneficial to the riverine and anadromous fish communities using dammed tributaries.

#### ***Comments***

Further development and ratification of the Great Lakes Fishery Commission, Habitat Advisory Board, 1998 Draft Binational Policy and Action Plan for the Protection and Enhancement of Aquatic Habitat in the Great Lakes should contribute significantly to furthering the goals of aquatic habitat protection and restoration in the Great Lakes basin.

Indicators 4510 & 4511 contribute to this indicator, as does indicator 72. Sentinel species should be the same for each of these indicators.

### ***Unfinished Business***

- < Need to develop a list of sentinel fish species.
- < Quantifiable endpoints and/or reference values need further development work.
- < The method of graphically displaying this indicator needs to be determined. Will bar graphs or maps be used to depict trends over time? What will appear on the graphs or maps?
- < There needs to be more information added to help better understand the trends presented by this indicator.

### ***Relevancies***

Indicator Type: state

Environmental Compartment(s): water

Related Issue(s): habitat

SOLEC Grouping(s): open waters, nearshore waters, coastal wetlands

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity

GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

# Salmon and Trout

## Indicator ID: 8

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### **Measure**

1) Productivity, yield, or harvest using abundance (e.g., catch of each species in a given unit of sampling effort), or biomass metrics; and 2) population of stocked and naturally produced fish.

### **Purpose**

To directly measure populations of introduced trout and salmon populations and to indirectly measure the potential impacts on native trout and salmon populations and the preyfish populations that support them.

### **Ecosystem Objective**

Meet FCGO for introduced trout and salmon species, consistent with FCGO for lake trout restoration and, in Lake Ontario, for Atlantic salmon restoration.

### **Endpoint**

Population is 100 % self-sustaining and meets FCGO harvest or yield targets. The following index targets for introduced trout and salmon species were provided in the FCGO for the upper three lakes:

Lake Huron: Annual Harvest of 2.4 million kg

Lake Ontario: Average Annual Yield of 2.4 kg/ha

Lake Michigan: Annual yields of chinook salmon - 3.1 million kg; coho salmon - 0.7 million kg; rainbow trout - 0.3 million kg; brown trout - 0.2 million kg.

Salmonine abundance should be great enough to keep alewife abundance below levels associated with the suppression of native fishes, but should also be below levels where predatory demand threatens the forage base and the integrity of the system.

### **Features**

This indicator will assess trends of Pacific salmon and rainbow and brown trout populations over time. These species were introduced into the Great Lakes ecosystem, are reproducing successfully in portions of the system, and can be considered to be permanent, "naturalized" components of the system. Stocking of these species continues to augment natural reproduction and enhance fishing opportunities, which is generally viewed favorably by the angling public. However, diversification of the salmonine component of the fish community is a significant departure from the historic dominance by lake trout; the impacts of diversification on native species and ecosystem function is not yet fully understood.

### **Illustration**

### **Limitations**

The data for this indicator are routinely collected and can be easily summarized on an annual basis. However, there will continue to be fisheries reliant on hatchery inputs so that this fraction will not reach 100 % in the immediate future. More analysis of existing data and evaluation of management alternatives through mathematical modeling is needed before more detailed species-by-species harvest can be defined.

### **Interpretation**

### **Comments**

Pacific salmon and Rainbow and Brown trout are introduced species. Some of these are now naturalized but stocking still occurs. These introduced species need to be treated differently than the lake trout. Atlantic salmon, which were native to Lake Ontario, have been introduced to the other four Great Lakes. If Atlantic salmon are introduced to the upper 4 Great lakes, they should be treated as exotics.

The salmonine community will consist of both wild and planted salmonines and exhibit increasing growth of, and reliance on, natural reproduction. Short-term restrictions of harvest may be required to achieve long-term goals of natural reproduction. Manipulation of the mix of salmonines should, in theory, result in higher catches than those produced solely by lake trout. The lake trout historically inhabited the whole water column, but its use of the pelagic food web (although substantial) could not have been as efficient as the contemporary species mix of lake trout and of pelagic piscivores--Pacific salmon, brown trout, and rainbow trout.

With finite prey and habitat resources for salmonine production, each species will exist at some expense to the others.

Fin clips used in past, nasal insert tags currently used in all larger fish released. Otolith, scale, and fin ray abnormalities used for fish smaller at release and for F2 and later recoveries.

### ***Unfinished Business***

- < There needs to be more information on the spatial and temporal trends this indicator will describe, as well as potential variability in the data.
- < The method of graphically displaying this indicator needs to be determined. For example, will bar graphs or maps be used to depict trends over time? What will appear on the graphs or maps?
- < There needs to be more information added to help better understand the trends presented by this indicator.

### ***Relevancies***

Indicator Type: state

Environmental Compartment(s): fish

Related Issue(s): toxics, nutrients, exotics, habitat

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s): Ontario, Huron, Michigan, Superior

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations



# Walleye and Hexagenia

## Indicator ID: 9

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### **Measure**

Abundance, biomass, or annual production of walleye and burrowing mayflies *Hexagenia* spp. populations in historical, warm-coolwater, mesotrophic habitats of the Great Lakes. Presence or absence of a *Hexagenia* mating flight (emergence) in late June- July in areas of historical abundance.

### **Purpose**

To directly measure status and trends in walleye and *Hexagenia* populations, and to indirectly assess the basic structure of warm-coolwater predator and prey communities; the health of percid populations; and the health of the Great Lakes ecosystem.

### **Ecosystem Objective**

Historical mesotrophic habitats should be maintained as balanced, stable, and productive elements of the Great Lakes ecosystem with walleye as the top aquatic predator of the warm-coolwater community and *Hexagenia* as a key benthic invertebrate organism in the food chain.

### **Endpoint**

Appropriate quantitative measures of abundance, yield, or biomass should be established as reference values for self-sustaining populations of walleye in mesotrophic habitats in each lake. The indicator for walleye can be based on the following index target abundances provided in the FCGOs):

Lake Huron-- Annual harvest: 0.7 million kg

Lake Michigan--Expected annual yield: 0.1-0.2 million kg

No reference values available for Lakes Superior, Erie, and Ontario.

The walleye is a highly valued species that is usually heavily exploited by recreational and (where permitted) commercial fisheries, and harvest or yield reference values established for self-sustaining populations probably represent an attempt to fully utilize annual production; as a result, harvest or yield reference values for these populations can be taken as surrogates for production reference values.

Target reference values for the indicator have not been developed for all major Great Lakes mesotrophic habitats.

### **Features**

The historical dominance of walleye and *Hexagenia* in mesotrophic habitats in the Great Lakes provides a good basis for a basin-wide evaluation of ecosystem health. Maintaining or reestablishing historical levels of abundance, biomass, or production and reestablishing self-sustaining populations of walleye and *Hexagenia* throughout their native range in the basin will help ensure dominance of these two species in the ecosystem and the maintenance of a desirable and balanced aquatic community in warm-coolwater mesotrophic habitats. *Hexagenia* are a major integrator between detrital and higher levels in food web. *Hexagenia* are highly visible during emergence in June-July and the public can easily use the species as an indicator to judge ecosystem health in areas where it is now abundant or was historically abundant but now is absent. Historical data can be used to develop status and trend information on walleye and *Hexagenia* populations. Commercial catch records for walleye in the Great Lakes extend back to the late 1800s; recreational catch data and assessment fishing data supplement these commercial catch records in some areas in recent years and are especially useful in areas where the commercial fishery for the species has been closed. Sediment cores from Lake Erie show major trends in abundance of *Hexagenia* extending back to about 1740 and other data are available to document more recent and present levels of abundance in Lake Erie and other parts of the basin.

### **Illustration**

### **Limitations**

Walleye abundance can be easily reduced by overfishing; harvest restrictions designed to promote sustained use are required if the species is to be used as an indicator of ecosystem health. The walleye element of the indicator cannot reliably diagnose causes of degraded ecosystem health. *Hexagenia* are extirpated at moderate levels of pollution, thus do not show graded response to severe levels of pollution. Target reference values for the indicator have not been developed for all major Great Lakes mesotrophic habitats.

### **Interpretation**

The desired trend is increasing dominance to historical levels of the indicator species in mesotrophic habitats throughout the basin. If the target values are met, the system can be assumed to be healthy; if the values are not met there is health impairment. The presence of an annual *Hexagenia* mating flight (emergence) in late June-early July can also be used by the public and other non-technical observers as a specific indicator of good habitat quality, whereas the lack of a mating flight in areas where the species was historically abundant can be used as an indicator of degraded habitat. High *Hexagenia*

abundance is strongly indicative of uncontaminated surficial sediments with adequate levels of dissolved oxygen in the overlying water columns. Probable causative agents of impairment for Hexagenia include excess nutrients and pollution of surficial sediments with metals and oil.

### **Comments**

Hexagenia were abundant in major mesotrophic Great Lakes habitats including Green Bay (Lake Michigan), Saginaw Bay (Lake Huron), Lake St. Clair, western and central basins of Lake Erie, Bay of Quinte (Lake Ontario), and portions of the Great Lakes connecting channels. Eutrophication and pollution with persistent toxic contaminants virtually extinguished Hexagenia populations throughout much of this habitat by the 1950s. Controls on phosphorus loadings resulted in a major recovery of Hexagenia in western Lake Erie in the 1990s. Reduction in pollutant loadings to Saginaw Bay has resulted in limited recovery of Hexagenia in portions of the Bay. Hexagenia production in upper Great Lakes connecting channels shows a graded response to heavy metals and oil pollution of surficial sediments.

Hexagenia should be used as a benthic indicator in all mesotrophic habitats with percid communities and percid FCGOs. Contaminant levels in sediment that meet USEPA and MOE guidelines for "clean dredged sediment" and IJC criterion for sediment not polluted by oil and petrocarbons will not impair Hexagenia populations. There will be a graded response to concentrations of metals and oil in sediment exceeding these guidelines for clean sediment. Reductions in phosphorus levels in formerly eutrophic habitats are usually accompanied by recolonisation Hexagenia, if surficial sediments are otherwise uncontaminated.

### **Unfinished Business**

- < A reference for the ecosystem objective is needed.
- < Has a quantitative endpoint for Hexagenia populations been developed? If not, then further development work is necessary for this indicator.
- < The method of graphically displaying this indicator needs to be determined. For example, will bar graphs or maps be used to depict trends in walleye and Hexagenia populations over time?

### **Relevancies**

Indicator Type: state

Environmental Compartment(s): biota, fish

Related Issue(s): toxics, nutrients, habitat

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s): Ontario, Erie, Huron

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 6: Degradation of benthos

# Preyfish Populations

## Indicator ID: 17

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### **Measure**

Abundance and diversity, as well as age and size distribution, of preyfish species (i.e., deepwater ciscoes, sculpins, lake herring, rainbow smelt, and alewives) in each lake.

### **Purpose**

To directly measure abundance and diversity of preyfish populations and to indirectly measure the stability of predator species necessary to maintain the biological integrity of each lake.

### **Ecosystem Objective**

To maintain a diverse array of preyfish populations to support healthy, productive populations of predator fishes as stated in the FCGOs for each lake. For Lake Michigan, the Planktivore Objective (GLFC, 1995) states: Maintain a diversity of prey (planktivore) species at population levels matched to primary production and to predator demands. This indicator also relates to the 1997 Strategic Great Lakes Fisheries Management Plan Common Goal Statement for Great Lakes Fisheries Agencies.

### **Endpoint**

This indicator will refer to index target abundances for preyfish — the values used to regulate the amount of predator fish stocked in each lake — provided in the FCGO for each lake as quantitative reference values that represent the necessary diversity and structure of the preyfish community. Lakes Huron, Michigan and Superior provide general guidelines for prey species prioritizing species diversity and a return to historical population levels. Lake Michigan FCGO proposed a lakewide preyfish biomass of 0.5 to 0.8 billion kg (1.2 to 1.7 million lbs.). Lake Ontario FCGO proposed an average annual biomass of 110 kilogram/hectare for the production of top predators.

### **Features**

An inadequate preyfish base might signal the need for reduction in predator species abundance by increasing harvest or reducing number of predator fish stocked. If preyfish populations also support a major recreational or commercial fishery, or are reduced significantly by entrainment mortality at water withdrawal sites in the Great Lakes, curtailment of these losses would be appropriate. Maintaining species diversity in the preyfish base may also require more detailed consideration and management of the predator species mix in the lake. Preyfish populations in each of the lakes is currently monitored on an annual basis. Changes in species composition, as well as changes in size and age composition of the major preyfish species, are available for review from long-term databases.

### **Illustration**

Lake-wide annual trends are displayed for each lake in barchart format. A GIS-based reporting system is under development that will show annual trends at multiple sampling locations within each lake.

### **Limitations**

Index target abundances, the quantitative reference values for this indicator, have not been established for all preyfish species in each lake.

### **Interpretation**

#### **Comments**

Diversity in preyfish species imparts some overall stability to the forage base by minimizing the effects of year-to-year variations typically experienced by a single species; therefore, managing the preyfish resource for the exclusive benefit of a single preyfish species, such as alewife, is not recommended. A substantial component of native preyfish species should be maintained, especially if new research implicates thiaminase in introduced preyfish species, such as alewives and rainbow smelt, as a major factor contributing to reproductive failure in lake trout and Atlantic salmon in the Great Lakes. There is interest expressed in some FGGOs in protecting or reestablishing rare or extirpated deepwater cisco preyfish species in their historic habitats in the Great Lakes. This should be reflected in future reference values for affected lakes.

#### **Unfinished Business**

< A discussion on how this indicator will be interpreted using the endpoint(s) is needed. For example, this indicator may need to be analyzed in conjunction with an indicator on primary production and/or predator species abundance and diversity.

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s): fish

Related Issue(s): toxics, nutrients, exotics, habitat

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring  
IJC Desired Outcome(s): 6: Biological community integrity and diversity  
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior  
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

# Sea Lamprey

## Indicator ID: 18

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### **Measure**

Number of spawning run adult sea lampreys; wounding rates on large salmonids.

### **Purpose**

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

### **Ecosystem Objective**

This indicator relates to the 1997 Strategic Great Lakes Fisheries Management Plan Common Goal Statement for Great Lakes Fisheries Agencies.

### **Endpoint**

This indicator will refer to the following index target abundances for sea lamprey populations provided in the Fish Community Goals and Objectives (FCGO) for each lake: Lake Huron: 75 % reduction by 2000; 90 % reduction by 2010. Lake Ontario: Limit population size to level that will not cause mortality in excess of 90,000 lake trout. Lake Michigan: Suppress population to achieve other FCGO. Lake Erie: Unspecified Objective. Lake Superior: 50 % reduction by 2000; 90 % reduction by 2010.

### **Features**

Control of sea lamprey populations is necessary to achieve other fish-community objectives because of the high mortality rates inflicted by lampreys on other fish. Spawning-run data are collected annually in selected streams; wounding data are collected annually in each lake. Long-term status and trend data are available.

### **Illustration**

Annual status and trend data on sea lamprey abundance and wounding rates are displayed in bar charts and tables by geographic area of interest.

### **Limitations**

Spawning-run estimates of parasitic populations must be based on a representative sampling of streams and must include large rivers. Reliable trapping and run estimates are often difficult or impossible to make for large rivers. Direct mark and recapture data for parasitic or larval phase sea lampreys is needed to provide better estimates and error terms, but these reliable, direct estimates may only be obtained in areas of high population abundance where large numbers of individuals can be marked and recaptured. Explicit estimates of variance is critical. Relating estimates of the spawning population to the resulting parasitic population assumes insignificant or at least constant mortality between the parasitic and spawning phases.

Wounding rates may be influenced by the abundance of prey in the suitable size range and may vary among major prey species depending on the mix of these fishes in an area. The season of data collection (e.g., spring or fall) affects the interpretation of the measure and must be kept constant. Classification of sea lamprey wounds (i.e., wounds or scars, Type A or Type B) is subjective and may vary among individuals and agencies making the observation.

### **Interpretation**

Increasing trap catches of spawning-run sea lampreys, numbers of streams with larval populations, and overall abundance of larvae in streams may indicate an expanding sea lamprey population. Increasing wounding rates in the presence of stable prey populations indicates an increase in sea lamprey abundance and in the amount of damage to prey populations. Data regarding total mortality in trout and salmon is also needed to properly interpret this indicator, since increasing total mortality in trout and salmon populations reduces the number of older fishes and the reproductive potential of these populations.

### **Comments**

Efforts are underway to improve the precision and accuracy of the measures of sea lamprey abundance and of the damage they inflict on trout and salmon populations in the Great Lakes. Improved measures will allow more precise interpretation of status and trend data and will help determine appropriate control measure responses.

### **Unfinished Business**

- < Need a more quantifiable endpoint for Lake Michigan.
- < Can an endpoint for wounding rates be developed?

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): fish

Related Issue(s): exotics

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity  
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior  
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

## Native Unionid Mussels

### Indicator ID: 68

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#### **Measure**

Distribution and abundance, reported as number of individuals per unit of sampling effort; soft tissue weight; and reproductive output of the Native Unionid mussel.

#### **Purpose**

To directly measure the population status of native Unionid populations and to indirectly measure the impact of the invading Dreissenid mussel on the Unionid mussel.

#### **Ecosystem Objective**

The diversity of native invertebrate fauna should be maintained in order to stabilize ecosystem habitats throughout the Great Lakes and their tributaries and connecting channels. Relates to IJC Desired Outcome 6: Biological community integrity and diversity.

#### **Endpoint**

Reestablish diverse, self-sustaining populations of native mussels in all historical habitats in the Great Lakes where they have been extirpated by the zebra mussel. Population characteristics should be equivalent to those in reference populations in these or similar habitats prior to the establishment of zebra mussels or where zebra mussels do not occur.

#### **Features**

Native Unionids 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 extinction by invading Dreissenids. Unionid mortality results both from attachment of Dreissenids to Unionid shells (biofouling) and from food competition with Dreissenids. Mortality can occur within two years of the initial Dreissenid invasion and extinction rate generally varies directly with Dreissenid population density. The type of habitat occupied by the Unionids also strongly influences their risk of extinction. For example, Unionids may be able to escape extinction in soft-bottomed habitats where they can burrow deeply and suffocate Dreissenids that attach to their shells. Unionids may also survive better in free-flowing streams than in streams with dams. In streams with dams, Dreissenids are most abundant in impoundments and tailrace areas. In free-flowing stream reaches and in streams without dams, Dreissenid populations rarely reach densities high enough to adversely affect Unionid populations.

#### **Illustration**

This indicator will be presented as a map showing population locations and population metrics throughout the Great Lakes basin.

#### **Limitations**

There is very little historical data on the distribution and abundance of Unionids in the Great Lakes basin and the available information (mainly from inland surveys conducted in the 1930s-1950s) is not quantitative. The highly clumped distributions typical of most Unionid populations makes sampling and population estimates problematic, and the difficulty in locating young animals impedes assessment of reproductive output.

#### **Interpretation**

Distribution and abundance of each Unionid species, reported as number of individuals per unit of sampling effort, provide a simple and direct measure of population status. Because Unionids tend to have clustered distributions, stratified, quadrat-timed searches or extinction search patterns performed by SCUBA divers offer the most promise for developing good population estimates. Soft tissue weight of individuals can be used as a measure of individual and population health. Tissue dry weight varies with season and reproductive status, but simple regressions comparing body weight to shell length can reliably reflect population health under each of these conditions. Individuals are considered at risk when tissue weight is less than 10% of the total (shell plus tissue) weight. Reproductive output can also be used as a measure of population health. Quantitative estimates of reproductive output are difficult to develop because young Unionids are traditionally very difficult to locate even in good habitat. However, the simple presence of young Unionids seems to be a reliable indicator of a healthy, reproducing population.

Additional data including total organic particulate matter in the water column and data about Dreissenid mussel populations are needed to interpret this indicator. Sites without Dreissenid mussels, with >12 species of Unionids, and with young Unionids present would be considered healthy sites where Dreissenids were having negligible impact. Sites where the Unionids are biofouled and the weight of attached zebra mussels is equal to or greater than the weight of the Unionid are sites where the Unionids can be expected to become extirpated shortly. Sites where total organic particulate matter in the water column averages less than 2 mg/L are sites where food resources are too limited to support remaining Unionid populations.

### **Comments**

The first step is to document where Unionids are located and what species are present. The second step is to determine if young Unionids of any species are present at a site. Secondary sampling efforts can focus on species of concern. The number of Unionid species at a given site in the Great Lakes basin varied widely. Most Unionid communities historically supported >12 species, depending on locality. Lake Huron probably never had more than 6-7 species, but Lake Erie and the connecting channels had 16-18, and the Unionid communities in inland waters in Michigan typically had about 16 species.

The northern riffleshell mussel, which occurred in Great Lakes connecting channels and perhaps in western Lake Erie, is listed by the U.S. government as "threatened" and action is being taken to change that listing to "endangered". That species is state-listed as "endangered". The Dreissenid mussel has probably exterminated northern riffleshell mussel populations in the connecting channels.

The species diversity and density of Unionids has severely declined in Lake Erie, the Detroit River, and Lake St. Clair since the arrival of Dreissenid mussels there in the mid-1980s. Species diversity of Unionids there has dropped from an average of 16 to less than 1. Many sites that historically supported Unionids now contain no live Unionids and no young (<5 years of age) have been found at these sites since about 1989.

### **Unfinished Business**

< Although there may not be an endpoint for population, as well as reproductive output, can an endpoint be provided for soft tissue weight? Can any goal for population and reproductive output be stated?

### **Relevancies**

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): exotics

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s):

Beneficial Use Impairment(s): 6: Degradation of benthos



## Fish Entrainment

### Indicator ID: 72

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#### **Measure**

1) Water withdrawal rates in m<sup>3</sup>/sec (gal/min) at once-through cooling at steam-electric and pumped-storage power plants in the Great Lakes; and 2) calculated total annual mortalities (losses) of sentinel species at each plant in each lake.

#### **Purpose**

To directly measure water withdrawal rates at once-through cooling at steam-electric and pumped-storage power plants in the Great Lakes and connecting channels, and to indirectly measure site-specific entrainment mortality of fishes by using water withdrawal rates to calculate an annual, aggregated, basin-wide estimate.

#### **Ecosystem Objective**

#### **Endpoint**

Reduced total annual losses of sentinel species to levels where compensatory survival can accommodate losses.

#### **Features**

This indicator will establish reference or baseline values for water withdrawal rates at once-through cooling at steam-electric and pumped-storage power plants in the Great Lakes and connecting channels, for use as surrogates to estimate site-specific entrainment mortality of fishes and provide annual, aggregated, basin-wide status and trends information on those losses. Large volumes of water are withdrawn from the Great Lakes and their connecting channels for use by industry and municipalities. Steam-electric power plant using once-through cooling, and pumped-storage hydropower plants withdraw the greatest volumes of water. Fish of all sizes are entrained with this water and substantial mortality occurs basin-wide among the entrained population. Larger fish can sometimes be excluded and mortality kept low if proper screening devices are employed. Small fish are virtually impossible to exclude and their entrainment and mortality can generally be calculated as the product of their density in the water being withdrawn and the water withdrawal rate. Rates of water withdrawal and associated fish mortality rates are known for existing steam-electric power plants using once-through cooling and for pumped-storage hydropower plants. Data are collected for all existing sites as part of the licensing process; water use rates are monitored routinely and can be easily reported. Review changes in water use biennially in conjunction with SOLEC.

#### **Illustration**

This indicator will display water withdrawal rates and associated entrainment mortality for years of record. It will also present water withdrawal rates for subsequent years when entrainment mortality data are lacking.

#### **Limitations**

Entrainment mortality factors vary from site to site requiring site-specific reporting, which is not readily available in Canada.

#### **Interpretation**

Reduction in water withdrawal rates or the addition of effective screening devices at existing facilities would reflect a reduction in fish entrainment mortality.

#### **Comments**

The purpose of the indicator is to minimize or reduce entrainment mortality in the Great Lakes and connecting channels by limiting the withdrawal of water or effectively screening water intakes, or both, at pumped-storage power plants and steam-electric using once-through cooling.

Aggregation, by lake or connecting channel, will provide useful information on waterbody-wide losses that can be used to assess impact and develop remediation strategies.

Remediation settlement recently paid for fish entrainment at one pumped-storage facility in the basin with a screened intake was valued at \$172 million.

Indicators 4510 & 4511 contribute to this indicator, as does indicator 6. Sentinel species should be the same for each of these indicators.

#### **Unfinished Business**

- < Need to develop a list of sentinel fish species.
- < Need to provide an ecosystem objective.
- < Quantifiable endpoints and/or reference values need further development work.

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): fish

Related Issue(s): habitat

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

# Lake Trout and Scud (*Diaporeia hoyi*)

## Indicator ID: 93

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### **Measure**

Abundance, yield, or biomass, and self-sustainability of lake trout and *D. hoyi* in coldwater, oligotrophic habitats of the Great Lakes.

### **Purpose**

To directly measure status and trends in lake trout and *D. hoyi* populations and to indirectly measure the basic structure of coldwater predator and prey communities and the general health of the ecosystem.

### **Ecosystem Objective**

Lake Superior should be maintained as a balanced, stable, and productive oligotrophic ecosystem with lake trout as the top aquatic predator of the coldwater community and *D. hoyi* as a key organism in the food chain. Oligotrophic waters in the other Great Lakes should be similarly maintained. Relates to Annex 1 of the GLWQA.

### **Endpoint**

In Lake Superior, lake trout stocks should be self-sustaining with a productivity >0.38 kg/ha/y; *Diaporeia hoyi* should be maintained throughout the lake at abundances of 220-320/m<sup>2</sup> at depths <100m and 30-160/m<sup>2</sup> at depths >100m.

Self-sustainability and appropriate lake-specific quantitative measures of abundance, yield, or biomass should be established as reference values in the other lakes. The reference values for lake trout in Lakes Michigan and Ontario can perhaps be based on target values provided in the FCGO for each lake:

Lake Michigan--Annual yield of 1.1 million kg

Lake Ontario--Adult population 0.5-1 million fish, average age of adult females of 7.5 yrs; annual recruitment of 100,000 juveniles.

No reference values are yet available for Lakes Huron and Erie. The lake trout is a highly valued species that is usually heavily exploited by recreational and (where permitted) commercial fisheries, and harvest or yield reference values established for self-sustaining populations probably represent an attempt to fully utilize annual production; as a result, harvest or yield reference values for these populations can be taken as surrogates for production reference values.

### **Features**

Self-sustainability of lake trout is measured in lakewide assessment programs carried out annually in each lake. The historical dominance of lake trout in oligotrophic waters in all of the Great Lakes provides a good basis for a basin-wide evaluation of ecosystem health. Maintaining or reestablishing historical levels of abundance, biomass, or production and reestablishing self-sustaining populations of lake trout throughout their native range in the basin will help ensure dominance of these two species in the ecosystem and the maintenance of a desirable aquatic community in oligotrophic, coldwater habitats. The desired trend is increasing dominance of the indicator species to historical levels in coldwater, oligotrophic habitats throughout the basin.

### **Illustration**

For each lake, a graph with lake trout and *D. hoyi* metrics on the x-axis and year on the y-axis will be presented.

### **Limitations**

The indicator is of greatest value in assessing ecosystem health in the oligotrophic, open-water portions of Lake Superior; it may be less useful in nearshore areas of the lake and the quantitative reference values for Lake Superior may not apply closely to oligotrophic areas of the other lakes. Target reference values for *D. hoyi* abundance have not been developed for all five lakes. Because the indicator includes only two species, it may not reliably diagnose causes of degraded ecosystem health. Also, because lake trout abundance can be easily reduced by overfishing, harvest restrictions designed to promote sustained use are required if the species is to be used as an indicator of ecosystem health. A number of lakewide surveys and assessments of benthic invertebrates communities have been made over the past several decades in the Great Lakes and the current status of *D. hoyi* populations is generally known, and an understanding of the changes related to the Dreissenid mussel invasion is emerging.

### **Interpretation**

Interpretation is direct and simple. If the target values are met, the system can be assumed to be healthy; if the values are not met there is health impairment. Causative agents of impairment are not addressed by the indicator.

### **Comments**

Stocked lake trout are tagged or marked so that the performance of different strains being tested can be evaluated.

Unmarked lake trout that are captured are examined in various ways to determine if they were produced by natural spawning. When the number of naturally spawned fish in the lake is judged to be sufficient to meet abundance or production or yield

goals outlined above or in Fish Community Goals and Objectives for lake trout, the population in the lake is judged to be self-sustaining. The lake trout populations in Lake Superior have recently been declared recovered and self-sustaining. Lake trout are reproducing successfully in portions of Lake Huron and Ontario, but the number of young produced annually and surviving to reproductive age is not yet sufficient to support numerical population goals established in the Fish Community Goals and Objectives (FCGO) for lake trout in these lakes. Lake trout abundance, yield, or biomass reference values are now generally met throughout the lower four Great Lakes by stocking lake trout.

### ***Unfinished Business***

#### ***Relevancies***

Indicator Type: state

Environmental Compartment(s): biota, fish

Related Issue(s): toxics, nutrients, exotics, habitat

SOLEC Grouping(s): open waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 6: Degradation of benthos

# Deformities, Erosion, Lesions and Tumors in Nearshore Fish

## Indicator ID: 101

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### **Measure**

Frequency of tumors and other related anomalies in nearshore fish.

### **Purpose**

To directly measure the deformities, erosion, lesions and tumors (DELT) index (Ohio EPA) in nearshore fish and to indirectly measure degraded habitat within the Great Lakes.

### **Ecosystem Objective**

Beneficial use impairment (IJC 1989).

### **Endpoint**

The Great Lakes shall be free of DELT above predetermined background levels (Annex 2, GLWQA).

### **Features**

Epizootics (sudden outbreaks) or elevated frequencies of tumors (neoplasms, including cancer) have become more frequent in the past three decades and have gained profile as indicators of beneficial use impairment of Great Lakes aquatic habitat and also as "early warnings" of potential impact on humans. Some tumors are genetically induced, others are virally induced, and a third group is considered to be chemically induced. There is a substantial body of evidence from field and laboratory studies showing that chemical carcinogens can cause tumors of the type included in this third group. These tumors typically affect the liver. External deformities other than external tumors, must be carefully evaluated if they are used to assess beneficial use impairment. The DELT anomaly index provides a tool for assessing the impact of such deformities.

A decline in PAH in river sediment in a Great Lakes tributary was accompanied with a decline in liver tumors in brown bullhead, suggesting restoration of Great Lakes aquatic habitats polluted with chemical carcinogens may be possible.

This indicator is similar to 4503, but applied to nearshore and offshore fish species rather than to coastal wetland species.

### **Illustration**

For each lake, a graph will be presented showing the DELT metric in a species or local population over time. The x-axis will show years and the y-axis will show the DELT metric.

### **Limitations**

The indicator is most useful in defining habitats that are heavily polluted and largely occupied by pollution tolerant fishes. Joint U.S.-Canada studies of benthic fishes in a gradient of polluted to pristine Great Lakes habitats using standardized methodology would greatly enhance our knowledge of the causes of tumors and their usefulness as indicators of ecosystem health.

### **Interpretation**

Tumor production is generally believed to be a response to a degraded habitat and toxic exposure to carcinogens, but may also be due to viral and bacterial agents. Incidences of tumor prevalence should be cross-correlated with location to determine trends. Impairment determinations will be based on a comparison of rates of occurrence of fish tumors or related anomalies at sites of interest with rates at unimpacted or least-impacted (reference) sites. Impairment occurs when:

1. An intestinal or liver tumor prevalence of >5% (rate at reference site exceeded by >5%) occurs in common native nearshore species of benthic dwelling fishes ( e.g., brown bullhead, black bullhead, white sucker, and several species of redhorse) or in walleye, yellow perch, or salmonid species offshore. Tumors are neoplasms of intestinal, bile duct, or liver cells, as determined by histopathology.
2. A prevalence of lip tumors >10%, or of overall external tumors >15% in any of the benthic species listed in 1 above. Tumors are papillomas or other neoplasms, as determined by histopathology.
3. A DELT (deformities, erosion, lesions, and tumors) Index (Ohio EPA) of > 0.5%. The fish species used in compiling the index is not limited to the species listed in 1 above.

### **Comments**

This indicator was prepared using information from:

Edsall, T., and M. Charlton. 1997. Nearshore waters of the Great Lakes. State of the Lakes Ecosystem Conference '96 Background Paper. ISBN 0-662-26031-7.

IJC. 1996. Indicators to evaluate progress under the Great Lakes Water Quality Agreement. Indicators for Evaluation Task Force. ISBN 1-895058-85-3.

***Unfinished Business***

- < A discussion of the potential limitations associated with this indicator (e.g., data collection, cost, etc.) Needs to be included.
- < On what basis can the subjective tags of “good” and “poor” be applied towards progress of the Beneficial Use Impairment.

***Relevancies***

Indicator Type: state

Environmental Compartment(s): fish

Related Issue(s): toxics

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances

IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s): 4: Fish tumors and other deformities

# Benthos Diversity and Abundance

## Indicator ID: 104

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### **Measure**

Species diversity and abundance in the aquatic oligochaete community.

### **Purpose**

To directly measure species diversity and abundance in the aquatic oligochaete community and to indirectly measure the relative health of the benthic community.

### **Ecosystem Objective**

This indicator addresses the general FCGO to protect and enhance fish habitat, achieve no net loss of the productive capacity of habitat supporting fish communities, and restore damaged habitats.

### **Endpoint**

Appropriate quantitative measures of species abundance and diversity should be established as reference values for a healthy, diverse benthic community.

### **Features**

Aquatic oligochaete community has been used as one index to assess the relative health of the benthic community. Oligochaetes are widespread and their abundances vary directly with the degree of organic enrichment. In addition, oligochaete species differ in their tolerances to polluted conditions; as organic enrichment declines, species composition shifts from pollution-tolerant to pollution-sensitive species. The desired trend is toward a diverse oligochaete community with inclusion of pollution-sensitive species.

### **Illustration**

For each lake, a graph showing the species composition and abundance of the oligochaete community on the y-axis and years on the x-axis will be presented to illustrate the changes in species metrics over time. A map will be used to show the major, within-lake, spatio-temporal differences.

### **Limitations**

Identifying oligochaete taxonomy is a highly specialized and time consuming activity that requires training and experience. Also, historical data is not housed in a data base and an endpoint for this indicator has not been established.

### **Interpretation**

Abundant, pollution-tolerant oligochaete species indicate degraded habitats. Increasing species diversity and decreasing abundance of oligochaetes indicate return to healthy habitats.

### **Comments**

This indicator covers benthic areas in which other indicators (Hexagenia and Diaporia) may be absent. Water depth has a strong effect on benthic community composition and should be standardized in any sampling design. Studies of benthic communities in Lake Erie, the Bay of Quinte, and the Detroit and St. Clair Rivers conducted in the early 1980s found changes in community structure of oligochaetes. In areas of western Lake Erie nearest major river mouths, and in the Bay of Quinte, a significant decline in oligochaete numbers suggests that a decline in organic enrichment occurred over the period. Near Cleveland Harbor, there was an increase in number of taxa, a reduction in the proportion of oligochaetes, and widespread distribution of pollution-sensitive forms not observed in the 1970s.

### **Unfinished Business**

- < May want to consider identifying specific species of interest to measure.
- < Need to quantify "abundant" and "diverse".
- < What will be the baseline to determine if species diversity is increasing or decreasing?

### **Relevancies**

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): toxics, nutrients, habitat

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s):

Beneficial Use Impairment(s): 6: Degradation of benthos

# Phytoplankton Populations

## Indicator ID: 109

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### **Measure**

Phytoplankton biomass (species and size composition) and size-fractionated primary productivity (Carbon-14 uptake or photosynthesis) as indicator of microbial food-web structure and function.

### **Purpose**

To directly measure microscopically species and size composition of phytoplankton biomass in the Great Lakes and to indirectly assess the impact of nutrient/contaminant enrichment and invasive exotic predators on the microbial food-web of the Great Lakes.

### **Ecosystem Objective**

Mesotrophic to oligotrophic conditions are needed to maintain healthy food-web dynamics and habitat integrity of the Great Lakes ecosystem.

### **Endpoint**

An endpoint needs to be established, based on an international literature search of current and historical data of temperate ecosystems to determine a range of biomass concentrations, species and size structure, as well as fractionated primary productivity (Carbon-14 uptake) for various size fractions as being indicative of healthy and mesotrophic to oligotrophic trophic status.

### **Features**

It is well known that the phytoplankton population and its productivity changes with anthropogenic pollution, both nutrients and contaminants. The ecosystem changes are reflected by the change of phytoplankton composition and productivity. For example, Lake Superior represents a pristine, healthy and ultra-oligotrophic ecosystem harboring a unique collection of phytoplankton species. Similarly, it is common knowledge that Lake Erie's phytoplankton composition, which was once eutrophic, has dramatically changed to meso-oligotrophic status due to phosphorous abatement and the invasion of zebra mussels. A great deal of data are available globally (temperate region) and in the Great Lakes about phytoplankton biomass, composition and primary productivity which will reflect the overall ecosystem health including grazing pressures of the exotic predators.

### **Illustration**

A table with list of species or a diagram can be given as an illustration.

### **Limitations**

Phytoplankton taxonomy (microscopic identification and enumeration) is a highly specialized and time consuming activity that requires intensive training and experience which is generally lacking in the Great Lakes. However, if properly done the phytoplankton analysis generates scientific, precise, and reliable species data that reflects the sensitivity of phytoplankton to anthropogenic stressors.

### **Interpretation**

#### **Comments**

The study of lower trophic levels and their use as indicators have been largely ignored in the Great Lakes. There is an immediate need to evaluate the microbial loop - the base of the food chain ranging from bacteria, heterotrophic nanoflagellates, autotrophic picoplankton, ciliates to phytoplankton (nanoplankton and microplankton-netplankton).

This indicator was prepared using information from:

M. Munawar, I.F. Munawar, P. Ross & R. Dermott. 1992. Exploring aquatic ecosystem health: A multi-trophic and an ecosystemic approach. *Jour. Aquat. Ecosyst. Health*. 1:237-252

M. Munawar, I.F. Munawar, L.R. Culp and G. Dupuis. 1978. Relative importance of nanoplankton in Lake Superior phytoplankton biomass and community metabolism. *Jour. Great Lakes Research*. 4:462-480

#### **Unfinished Business**

- < Need a reference for the ecosystem objective.
- < An endpoint needs to be established.
- < The method of graphically displaying this indicator needs to be determined.
- < Additional information is needed to interpret the data as well as a range of "good" or "poor" (e.g., an oligotrophic ecosystem that harbors phytoplankton populations that are diverse in species and size would indicate a healthy ecosystem.)



**Relevancies**

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): toxics, nutrients

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 8: Absence of excess phosphorus

GLFC Objective(s):

Beneficial Use Impairment(s): 13: Degradation of phyto/zooplankton populations

# Phosphorus Concentrations and Loadings

## Indicator ID: 111

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### **Measure**

Total phosphorus levels (ug/L).

### **Purpose**

To directly measure total phosphorus levels in the Great Lakes and to indirectly measure degradation of the aquatic ecosystem and the loss of beneficial uses and to indirectly measure human-induced causes of phosphorus loadings.

### **Ecosystem Objective**

Annex 3 of the GLWQA outlines specific goals in phosphorus reduction and provides objectives for each lake. The IJC developed the following delisting guideline for eutrophication or undesirable algae: 'no persistent water quality problems (e.g., dissolved oxygen, depletion of bottom waters, nuisance algal blooms or accumulations, and decreased water clarity) attributed to cultural eutrophication.'

### **Endpoint**

To meet GLWQA target of 10 ug/L for Lake Ontario, and the Central and Eastern basins of Lake Erie and 15 ugP/L for western Lake Erie. Target endpoints need to be established for Lakes Superior, Michigan, Huron, and Ontario that will manage loadings to prevent noxious algal blooms, scums, taste and odor clarity problems, beach accumulations of Cladophora and yield 50-60 million lbs good fish/yr.

### **Features**

Analysis of phosphorus loadings and concentrations to the Great Lakes is ongoing and reliable. Current methodology used for analysis is adequate. This indicator provides information on the baseline productivity of the lake, and linkages to future biological problems related to return to excess nutrient loads. Also, the filtering effects of new colonizing species -- zebra and quagga mussels -- appear to exacerbate the effects of declining phosphorus loading (hence declining lake productivity). Measurements and reporting must reliably reflect spatio-temporal differences on scales needed to effectively address the ecosystem objective. Particular emphasis should be placed on open-lake data collected in the spring of the year, and comparison should be made with the proposed GLWQA objectives. Remote sensing and satellite imagery can be used to identify blooms, as can reports of nuisance algal growth, especially along shorelines. Monthly surveillance data are available for the years 1976 - 1981. Biannual survey data available for 1982 to present are also available.

### **Illustration**

For each lake, a graph will be presented showing total phosphorus on the y-axis and years on the x-axis. A map will be presented showing major, within-lake, spatio-temporal distributions.

### **Limitations**

Lakewide surveys to measure total phosphorus are not conducted biannually in all five lakes.

### **Interpretation**

Desirable outcomes are a decrease in frequency or the absence of blooms of undesirable algae and a decrease in total phosphorus toward target levels specified in the GLWQA.

### **Comments**

This indicator was prepared using information in:

Edsall, T., and M. Charleton. 1997. Nearshore waters of the Great Lakes. State of the Lakes Ecosystem Conference '96 Background Paper. ISBN 0-662-26031-7.

Charleton, M., and R. LeSage. 1999. Lake Erie in Transition: the 1990s. In State of Lake Erie (SOLE). M. Munawar, T. Edsall, and I. F. Munawar (eds.) Backhuys Publishers, Leiden, The Netherlands (In Press).

### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): water

Related Issue(s): nutrients

SOLEC Grouping(s): open waters, nearshore waters, coastal wetlands

GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of phosphorus, 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 8: Absence of excess phosphorus

GLFC Objective(s): Erie

Beneficial Use Impairment(s): 8: Eutrophication or undesirable algae

# Contaminants in Recreational Fish

## Indicator ID: 113

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### **Measure**

Concentration of PBT chemicals in the catch-weighted average, edible tissue of recreational fish.

### **Purpose**

To directly measure levels of PBT chemicals in fish and to indirectly measure the potential harm to human health through consumption of contaminated fish.

### **Ecosystem Objective**

Fish should be safe to eat.

### **Endpoint**

### **Features**

This indicator will be used to monitor fluctuations in the concentration of contaminants in the average fish from each Great Lake. The average fish concentration is defined as the average PBT concentration for each fish-species weighted by the proportion of that species' mass caught in each Great Lake. Estimation of this index entails no new sampling or analytical costs. Catch records, by species, are available from the Great Lakes Fishery Commission. Concentrations of contaminants in dominant fish species are collected by several of the States and the Ontario Ministry of the Environment and Energy. This index will be calculated every two years based on best available data and appropriate statistical methods. To make calculation of the index manageable, uncommon species – those making up less than 5% of the total catch by weight -- will not be considered. To account for cooking losses and the fact that most consumers skin their fish or do not eat skins, final PBT concentrations (except for mercury) in fillets with skins will be multiplied by 50%.

### **Illustration**

The calculated average will be depicted on simple bar graphs showing the fluctuation of PBT concentrations in the average fish over time and space. As reduction in chemical concentrations is an exponential process, time trends should be depicted on a logarithmic Y-axis. Average concentrations will be depicted with tissue guidelines for consumption advisories to illustrate the average consumability, according to existing advisory standards, of the recreational fish from each Great Lake.

### **Limitations**

This indicator pertains to the representative fish catch of recreational anglers from the Great Lakes. This index specifically should not be used to assess risk to populations that consume fish species that have PBT concentrations that are higher or lower than average.

### **Interpretation**

### **Comments**

To understand the magnitude of a risk, citizens and regulatory personnel need to know risks posed to the average consumer as well as those pertaining to the most-exposed, most sensitive sub-groups. As opposed to estimators of worst-case exposure, average fish concentrations are unbiased indicators. As indicators of central tendency, average concentrations are necessary to estimate likely risks and risks to the population as a whole.

### **Unfinished Business**

- < Need to determine the specific PBT chemicals that will be measured.
- < Need to define the ecosystem objective to be referenced.
- < Need to define/develop endpoints. Will action levels be used as reference?

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): fish

Related Issue(s): toxics

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances

IJC Desired Outcome(s): 1: Fishability, 4: Healthy human populations, 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior

Beneficial Use Impairment(s): 1: Restrictions on fish and wildlife consumption

# Contaminants in Young-of-the Year Spottail Shiners

## Indicator ID: 114

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### **Measure**

Concentration of PBT chemicals in young-of-the-year spottail shiners.

### **Purpose**

To directly measure levels of PBT chemicals in young-of-the-year spottail shiners and to indirectly measure potential harm to fish-eating wildlife.

### **Ecosystem Objective**

Forage fish concentrations of PBT chemicals should not pose risk to fish-eating wildlife.

### **Endpoint**

### **Features**

This indicator will be used to monitor long-term fluctuations in the concentration of measured contaminants and the risk they pose to fish-eating wildlife. Shiner collections have been ongoing for almost two decades and represent one of the best long-term data bases on chemicals in the Great Lakes. Because young-of-the-year spottail shiners are small and stay close to their natal area, their chemical concentrations provide information on local chemical inventories as well as the variability and distribution of the chemicals throughout the lakes. The shiners are captured from several spots on each Lake; therefore, the data can be used to illustrate both variability and average levels of PBT chemical exposure to fish-eating wildlife throughout the lakes

### **Illustration**

Results of raw data will be used to construct simple bar graphs showing the fluctuation of contaminants over time and space. As decline of chemicals is an exponential decline, these graphs will be depicted on an logarithmic Y axis versus time.

### **Limitations**

Trends of chemical contaminants in spottail shiners are confounded by other factors including: food chain effects, potential weather effects, analytical and sampling variability. These factors limit the usefulness of the shiner data as an indicator of short-term trends of PBTs in the Great Lakes. Larger, older forage fish may have higher PBT concentrations than young-of-the-year spottail shiners, and therefore, shiner data may underestimate risk to fish-eating wildlife.

### **Interpretation**

### **Comments**

Concentrations of contaminants in young-of-the-year spottail shiners represent a good indicator of local concentrations of chemicals and potential risk to fish-eating wildlife.

### **Unfinished Business**

- < Need to provide the names of the PBT chemicals will be measured by this indicator.
- < Need to provide a reference for the ecosystem objective.
- < An endpoint, or frame of reference in which to interpret the data, needs to be defined.

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): fish

Related Issue(s): toxics

SOLEC Grouping(s): nearshore waters

GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s):

# Contaminants in Colonial Nesting Waterbirds

## Indicator ID: 115

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### **Measure**

- 1) Annual concentrations of DDT complex, PCBs/PCDFs/PCDDs and other organic contaminants and Hg and other metals in Herring Gull eggs from 15 sites from throughout the Great Lakes (U.S. and Canada).
- 2) Periodic measurement of biological features of gulls and other colonial waterbirds known to be directly or indirectly impacted by contaminants and other stressors. These include (but are not limited to): clutch size, eggshell thickness, hatching and fledging success, size and trends in breeding population, various physiological biomarkers including vitamin A, immune and thyroid function, stress hormone levels, liver enzyme induction, PAH levels in bile and porphyrins and genetic and chromosomal abnormalities.

### **Purpose**

To directly measure chemical concentration levels in colonial waterbirds and to indirectly measure the impact of these contaminants on the colonial waterbird population and other aquatic wildlife.

### **Ecosystem Objective**

### **Endpoint**

Chemical levels and biological measures in colonial nesting waterbirds are not different from those from reference sites in Atlantic Canada or from the Prairies.

### **Features**

Although there are Great Lakes wildlife species that are more sensitive to contaminants than Herring Gulls, and colonial nesting waterbird species in general, there is no other species which has the historical dataset that the Herring Gull does. As contaminant levels continue to decline (if they do), the usefulness of the Herring Gull as a biological indicator species may lessen (due to its reduced sensitivity to low levels of contamination) but its value as a chemical indicator will remain and probably increase - as levels become harder and harder to measure in other media. As well, it is an excellent accumulator. 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 usually made up primarily of fish, they are an excellent terrestrially nesting indicator of the aquatic community. Historical data on levels of chemical contamination in gull eggs are available, on an annual basis, for most sites in both the Canadian and U.S. Great Lakes dating back to the early 1970s. An immense database of chemical levels and biological measures from the Great Lakes, as well as many off-Lakes sites, is available from CWS. For Herring Gulls, many of the above biological measures are correlated with contaminant levels in their eggs. In other colonial waterbirds there are similar correlations between contaminant levels in eggs and various biological measures. Contaminant levels in eggs of other colonial waterbirds are usually correlated with those in Herring Gulls.

### **Illustration**

- 1) Temporal trends, portrayed as annual contaminant levels over time, for 1974-present in most instances, are available for each site and each compound, for example, DDE, 1974-1997, for Toronto Harbour and could be displayed graphically.
- 2) Geographical patterns in contaminant levels, showing all sites relative to one another, are available for most years 1974-present and for most compounds, for example, PCBs, 1997, at 15 Great Lakes sites from Lake Superior to the St. Lawrence River (including U.S. sites) and could be displayed on both maps and graphs.

### **Limitations**

Herring Gulls are highly tolerant of persistent contamination and may underestimate biological effects occurring in other less monitored, more sensitive species. Also, some adult Herring Gulls from the upper Lakes, especially Lake Superior, move to the lower Lakes, especially Lake Michigan, during harsh winters. This has the potential to confound the contaminant profile of a bird from the upper Lakes. Most of the gull's time is still spent on its home lake and this has not been noted as a serious limitation up to this point. Using contaminant accumulation by young, flightless gulls would eliminate this problem but their contaminant levels and effects would be less due to the much reduced contaminant exposure/intake.

### **Interpretation**

Other tissues and species analyzed as necessary to confirm findings in Herring Gulls.

### **Comments**

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 being put upon physiological and genetic biomarkers. These are not as well characterized, nor are they understood as easily by the public. Other complementary species include: Double-crested Cormorant (*Phalacrocorax auritus*), Common Tern (*Sterna hirundo*), Caspian Tern (*Sterna caspia*) and Black-crowned Night-Heron (*Nycticorax nycticorax*). The Herring Gull egg contaminants dataset is the longest running continuous contaminants dataset for wildlife in the world.

1) Chemical levels and trends: Contaminant levels in almost all Great Lakes colonial waterbirds are significantly and substantially reduced from what they were 25 years ago. However, now, in the 1990s, year to year differences in contaminant levels are quite small and without statistical analysis it is often difficult to tell if a compound has stabilized" and is undergoing only year to year, non-significant, fluctuations or if it is still declining. Our analyses show that most contaminants at most sites are continuing to decline at a rate similar to what they have over the last decade or two. However, some compounds, at some sites, have stabilized. Geographical differences for a given compound among sites on the Great Lakes are not as dramatic as they once were. There is greater similarity in contaminant concentration among Great Lakes sites now than there was in the past. However, differences in contaminant levels between sites on and off the Great Lakes are still fairly evident.

2) It is difficult to show consistent differences in biological effects among colony sites within the Great Lakes. This is probably due to the great overall reduction in contaminant levels as well as the lessening in differences among Great Lakes sites. The comparisons which show the greatest differences for biological effects of contaminants are between sites on and off the Great Lakes.

### ***Unfinished Business***

< Need to an ecosystem objective that this indicator addresses and provide a reference.

### ***Relevancies***

Indicator Type: pressure

Environmental Compartment(s): biota

Related Issue(s): toxics

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s): Erie

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 5: Bird or animal deformities or reproductive problems

# Zooplankton Populations

## Indicator ID: 116

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### **Measure**

1) Community Composition; 2) Mean Individual Size; and 3) Biomass and Production.

### **Purpose**

To directly measure changes in community composition, mean individual size, biomass and production of zooplankton populations in the Great Lakes basin, and to indirectly measure changes in food-web dynamics due to changes in vertebrate or invertebrate predation, and changes in system productivity; the type and intensity of predation; and energy transfer within a system.

### **Ecosystem Objective**

Maintain the biological integrity of the Great Lakes and to support a healthy and diverse fishery as outlined by the Goals and Objectives of the LaMPs and Great Lakes Fishery Commission.

### **Endpoint**

For mean individual size, Mills et al. (1987) suggest 0.8 mm as an optimal size when the water column is sampled with a 153- $\mu$ m mesh net. Endpoints for community composition and biomass and productivity depend on the desired trophic state and type of fish community. Zooplankton as indicators of plankton and ecosystem community health are still in the early stages of development. Some information on the variability in zooplankton mean length is presented in Mills et al. (1987), and Johannsson et al. (1999b,c). Empirical relationships can be found in the literature relating zooplankton biomass and production to other state variables, such as total phosphorus, chlorophyll a concentration, primary production and zooplankton mean length (Makarewicz and Likens 1979 (if rotifers are measured), (McCauley et al. 1980), Hanson and Peters 1984, Yan 1985, McQueen et al. 1986, Johannsson et al. 1999a). End points for community structure are not clear now that new exotic zooplankton (Bythotrephes and Cercopagus) have entered the lakes.

### **Features**

This indicator tracks trends in zooplankton populations, including community composition, mean individual size, and biomass and production, over time. Some data are available for Lake Ontario from 1967, 1970, 1972 on composition and abundance. Composition, density, biomass and production data are available for 1981-1995 from the DFO Lake Ontario Long-Term Biological Monitoring (Bioindex) Program (Johannsson et al. 1998). Mean individual size was not measured for the community during these years, but could be obtained from archived samples. Zooplankton work on Lake Erie has been reviewed by Johannsson et al. (1999c).

### **Illustration**

Zooplankton mean length, ratio of calanoids to cladocerans + cyclopoids and biomass can be presented as line graphs if trend data is available. Shifts in composition might be better tracked using factor analysis followed by multi-dimensional scaling to show how the community structure moves in a two-dimensional space.

### **Limitations**

At this point, it is not possible to rate mean individual size of zooplankton if they do not equal 0.8 mm. It is unclear how different energy flow is if the mean size is 0.6 mm or 1.0 mm, and if 0.6 mm is equivalent to 1.0 mm.

### **Interpretation**

Some of the other measures which would help with the interpretation of the zooplankton data would include, total phosphorus, chlorophyll a, temperature, oxygen (in some regions), and if possible primary production and phytoplankton composition and biomass.

### **Comments**

**Composition:** Changes in composition indicate changes in food-web dynamics due to changes in vertebrate or invertebrate predation, and changes in system productivity. Ratios such as calanoids to cladocerans + cyclopoids have been used to track changes in trophic. This particular ratio may NOT work in dreissenid systems (Johannsson et al. 1999c).

**Mean Individual Size:** The mean individual size of the zooplankton indicates the type and intensity of predation. When the ratio of piscivores to planktivores is approximately 0.2, the mean size of the zooplankton is near 0.8 mm. These conditions are characteristic of a balanced fish community (Mills et al. 1987). There is a high degree of variability about this relationship and further work needs to be done to strengthen this indicator. Total biomass and possibly production decrease with decreases in the mean size of the zooplankton (Johannsson et al. 1999b).

**Biomass and Productivity:** Biomass can be used to calculate production using size and temperature dependent P/B ratios for each of the major zooplankton groups. Production is a much better indicator of energy transfer within a system than abundance or biomass.

Of these measures, composition and mean size are the most important. However, these factors provide the information needed to calculate biomass and production.

### **References:**

- Hanson, J.M. and R.H. Peters. 1984. Empirical prediction of crustacean zooplankton biomass and profundal macrobenthos biomass in lakes. *Can. J. Fish. Aquat. Sci.* 41: 439-445.
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- McQueen, D.J., J.R. Post, and E.L. Mills. 1986. Trophic relationships in freshwater pelagic ecosystems. *Can. J. Fish. Aquat. Sci.* 43: 1571-1581.
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- Yan, N.D. 1985. Empirical prediction of crustacean zooplankton biomass in nutrient-poor Canadian shield lakes *Can. J. Fish. Aquat. Sci.* 43: 788-796.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): toxics, nutrients

SOLEC Grouping(s): open waters, nearshore waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s): 13: Degradation of phyto/zooplankton populations



# Atmospheric Deposition of Toxic Chemicals

## Indicator ID: 117

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### **Measure**

Annual average loadings of IJC priority toxic chemicals from the atmosphere to the Great Lakes, based on measured atmospheric concentrations of the chemicals, as well as wet and dry deposition rates.

### **Purpose**

To directly measure the annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes and to indirectly measure potential impacts of toxic chemicals from atmospheric deposition on human health and the Great Lakes aquatic ecosystem, as well as to indirectly measure the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

### **Ecosystem Objective**

The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life.

### **Endpoint**

Atmospheric concentrations of IJC priority toxic chemicals are no longer measurable by current technology.

### **Features**

This indicator will track whether concentrations of the IJC priority toxic chemicals are, as a group, decreasing, staying the same, or increasing in open waters over time. Loadings will be calculated based on 1) measured atmospheric concentrations of the chemicals and 2) wet and dry deposition rates using techniques described in the "Chemicals of Concern" chapter of the Lake Superior Stage II LaMP. The indicator data will also demonstrate the magnitudes of the trends in the loadings of toxic chemicals from the air to the water. The magnitudes of the trends are expressed as a "half-fold time," or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals.

### **Illustration**

### **Limitations**

There is concern that some of the features of the loadings calculations (see Comments field) are poorly known at present. The trends in the atmospheric concentrations of toxic chemicals, however, are much better known and a much better indicator of progress towards virtual elimination. Errors in these trends should be clearly stated and tested against the null hypothesis (things are not changing).

### **Interpretation**

Progress will be determined based on whether trends of the IJC priority toxic chemicals are positive (i.e., increasing pollutant concentrations) or negative (decreasing pollutant concentrations) and by the number of chemicals which reach the virtual elimination goal.

To understand the pollutant concentration trends related to atmospheric deposition, additional information is needed in interpreting pollutant load estimates derived using the suggested calculation (see Comments field). For example, information on the yearly variations in the rain rate (dry years versus wet years) is needed to understand the pollutant concentrations associated with wet deposition. Also, since it is known that the pollutant loads associated with atmospheric deposition have seasonality for some components, the data should be statistically deseasonalized to properly determine the trend.

### **Comments**

Estimates of atmospheric deposition have been made since 1988 (Strachan and Eisenreich, 1988; Eisenreich and Strachan, 1992). More recently atmospheric deposition fluxes and loads have been measured by the Integrated Atmospheric Deposition Network (IADN) (Hoff et al., 1996; IADN Steering Committee, 1997). The indicator follows procedures set out in the IADN Quality Assurance Program Plan (1994). Several primary indicators of progress towards virtual elimination are found in the estimation of loading to the lakes, L, where  $L = W + D + G$ , below.

Wet deposition (W) is calculated as:

$$W(\text{ng m}^{-2} \text{y}^{-1}) = 1000 C_p R_p$$

where  $C_p$  (ng/l) is the volume-weighted mean precipitation concentration averaged over a year period,  $R_p$  is the precipitation rate in  $\text{m y}^{-1}$  (water equivalent for snow), and the factor of 1000 converts litres to cubic metres.

The magnitude of W and its change with time is an indicator of progress towards virtual elimination. It should be noted, however, that yearly variations in the rain rate (dry years versus wet years) will complicate the interpretation of the indicator. Therefore, the concentration of the chemical in precipitation should also be evaluated as an indicator.

Dry deposition of particles is calculated from:

$$D(\text{ng m}^{-2} \text{y}^{-1}) = v_d C_{a,\text{part}}$$

where  $v_d$  ( $\text{m y}^{-1}$ ) is the dry deposition velocity of the species in question (a function of particle size and hygroscopic nature of the particles) and  $C_{a,\text{part}}$  ( $\text{ng m}^{-3}$ ) is the particulate phase concentration of the chemical in air. Since the dry deposition velocity of particles is not well known, it has been specified as  $0.2 \text{ cm s}^{-1}$  in previous work (Strachan and Eisenreich, 1988; Hoff et al. 1996). Since the deposition velocity is not expected to be a determining factor in the long-term trend of dry deposition (particle sizes will not change much with time), the air concentration of chemicals on the particles will be a primary indicator which can be tracked for trends.

Gas exchange is computed from the knowledge of both the gas phase species concentration in air ( $C_{a,\text{gas}}$ ,  $\text{ng m}^{-3}$ ) and the concentration of the chemical in water ( $C_w$ ,  $\text{ng/l}$ ) through the formula:

$$G(\text{ng m}^{-2} \text{y}^{-1}) = k_{oL} \left( C_{a,\text{gas}} \frac{RT}{H} - 1000 C_w \right)$$

where  $k_{oL}$  ( $\text{m y}^{-1}$ ) is the air-water mass transfer coefficient, H is the temperature dependent Henry's Law constant, R is the gas constant and T is the surface water skin temperature (Schwarzenbach et al., 1993). As expressed above if  $G > 0$  then the lakes are being loaded from the atmosphere and if  $G < 0$  then the lakes are a source of the chemical to the atmosphere. There is uncertainty (see below) in some of the chemical and physical properties which are part of the gas phase flux. A more precise indicator of trends in this flux are the air and water concentrations of the chemical themselves.

The rate of change of the loading,  $L = W + D + G$ , is  $dL/dt$ . Since it is known that the loads have seasonality for some components, in order to properly determine the trend, the data should be statistically deseasonalized (i.e., using a Rank-Kendall statistic, standard temperature correction, or equivalent).

Even after deseasonalizing the trend data, there may be considerable error in the magnitude of the gas phase exchange. In order not to overstate the loading indicator precision, a secondary measure of the indicator will be the sign of the change in L, in the above equation. If the indicator is positive, the trends in the loadings are increasing and the objective is not being approached. If the indicator is negative, the loadings are decreasing and the objective is being approached. It is likely that if the sign of  $dL/dt$  is negative, the change in the atmospheric contributions to the tributary loadings is likely to be of the same sign.

A third component of the indicator is the relative rate of change of the loading with time. The more negative this indicator becomes the faster the goal of virtual elimination will be reached.

Hoff, R. M. W. M. J. Strachan, C.W. Sweet, C. H. Chan, M. Shackleton, T.F. Bidleman, K. A. Brice, D. A. Burniston, S. Cussion, D.F.Gatz, K. Harlin, and W.H. Schroeder. 1996. Atmospheric Deposition of Toxic Chemicals to the Great Lakes: A Review of Data through 1994, Atmos. Environ. 30, 3505-3527.

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Eisenreich, S. J. and W.M.J. Strachan. 1992. Estimating Atmospheric Deposition of Toxic Substances to the Great Lakes - An Update. Report 6-1992. Gray Freshwater Biological Institute, University of Minnesota, P. O. Box 100, Navarre, MN 55392

Strachan, W.M. J. and S. J. Eisenreich. 1988. Mass Balancing of Toxic Chemicals in the Great Lakes: The Role of Atmospheric Deposition. Publ. International Joint Commission, Windsor, Canada, July, 113 p.

Schwarzenbach, R. P., Gschwend, P.M., and D.M. Imboden. 1993. Environmental Organic Chemistry, Wiley Interscience Publishers, New York.

### **Unfinished Business**

- < Need to provide the list of the specific IJC priority toxic chemicals that will be monitored for this indicator.
- < Need to provide a detailed description of how data will be displayed graphically. For example, will the illustration consist of various colored plottings on a map or a bar chart to convey the relative abundance?

**Relevancies**

Indicator Type: pressure

Environmental Compartment(s): air, water

Related Issue(s): toxics

SOLEC Grouping(s): open waters

GLWQA Annex(es): 11: Surveillance and monitoring, 12: Persistent toxic substances, 15: Airborne toxic substances, 17: Research and development

IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s):

# Toxic Chemical Concentrations in Offshore Waters

## Indicator ID: 118

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### **Measure**

The concentration of IJC priority toxic chemicals in the offshore waters of the Great Lakes.

### **Purpose**

To directly measure the concentration of priority toxic chemicals in offshore waters and to indirectly measure the potential impacts of toxic chemicals on human health and the Great Lakes aquatic ecosystem, as well as to indirectly measure the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

### **Ecosystem Objective**

The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life.

### **Endpoint**

Concentrations of IJC priority toxic chemicals in the offshore waters of the Great Lakes are no longer measurable by current technology.

### **Features**

This indicator will track whether concentrations of the IJC priority toxic chemicals are, as a group, decreasing, staying the same, or increasing in open waters over time. The indicator data will also demonstrate the magnitudes of the trends of the various chemicals. The magnitudes of the trends are expressed as a "half-fold time," or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals. Monitoring for this indicator will occur during the two year periods between SOLEC. Every two years, water concentrations of zero discharge and lakewide remediation chemicals should be monitored throughout the offshore waters of Lake Superior, for comparison with an appropriate baseline. Sampling should be conducted during spring, isothermal conditions, as maximum concentrations have been reported during this time.

### **Illustration**

Water concentrations of the zero discharge and lakewide remediation chemicals should be presented in a table which provides both the 95<sup>th</sup> percentile (see Interpretation field) and the appropriate baseline, for comparison. Spatial distribution maps, showing raw concentration data, should also be provided to indicate spatial gradients and to discern any problem areas.

### **Limitations**

Although measurements exist for many priority chemicals in the Great Lakes system, these measurements are not all obtained on a time scale that would allow for significant reinterpretation every two years. As new information is available, and the indicator is updated, trends will become more discernable and progress toward virtual elimination can be assessed. Errors in these trends should be clearly stated and tested against the null hypothesis (i.e., things are not changing).

### **Interpretation**

Pollutant concentrations will be considered positive only if 95-100% of the available data indicate concentration levels below the lake-specific baseline. Progress will be determined based on whether trends of the IJC priority toxic chemicals are positive (i.e., increasing pollutant concentrations) or negative (decreasing pollutant concentrations) and by the number of chemicals which reach the virtual elimination goal.

### **Comments**

#### **Unfinished Business**

- < Need to provide the list of the specific IJC priority toxic chemicals that will be monitored for this indicator.
- < Need to provide a detailed description of how data will be displayed graphically. For example, will the illustration consist of various colored plottings on a map or a bar chart to convey the relative abundance?

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s): water

Related Issue(s): toxics

SOLEC Grouping(s): open waters

GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances

IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s):

# Concentration of Contaminants in Sediment Cores

## Indicator ID: 119

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### **Measure**

The concentrations of IJC priority toxic chemicals in sediment cores at selected sites within the Great Lakes at ten year intervals.

### **Purpose**

To directly measure concentrations of IJC priority toxic chemicals in sediments and to indirectly measure potential harm to aquatic ecosystems by contaminated sediments, as well as to indirectly measure the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

### **Ecosystem Objective**

The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life. And, GLWQA Annex 14 Objective asks to identify the nature and extent of sediment pollution of the Great Lakes System.

### **Endpoint**

Sediment concentrations of IJC priority toxic chemicals are no longer measurable by current technology.

### **Features**

This indicator will track whether concentrations of the IJC priority toxic chemicals are, as a group, decreasing, staying the same, or increasing in open waters over time. The indicator data will also demonstrate the magnitudes of the trends of the various chemicals. The magnitudes of the trends are expressed as a "half-fold time," or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals.

In the nearshore areas and harbours and bays, cores would be collected every 10 years from sites selected for index monitoring. Index sites should include areas where sediment sampling would provide added value to contaminant investigations, for example, sites previously monitored for contaminants in sculpin (DeVault et al., 1998). Sites would also be chosen based on sediment type, expected sedimentation rates, and proximity to potential sources. Cores would be sectioned, dated and analyzed for the zero discharge<sup>1</sup> and lakewide remediation<sup>2</sup> chemicals. Sediment concentrations for recent years (i.e., last 10 years) would be compared against the Smith and Smith (1993) yardsticks.

Certain estuaries, bays, and harbours on the lakes, are designated as Areas of Concern because of past or on-going pollution problems. Sediment contamination in these areas, taken together, represent cumulative impacts to productive habitat areas. In addition, Areas of Concern can serve as contaminant source areas to the rest of the Lakes. Application of the sediment indicator at Areas of Concern is intended to integrate the information gathered by RAP monitoring efforts to give a lakewide picture for these important habitat areas. In the Areas of Concern, sediment concentrations of zero discharge and lakewide remediation chemicals would be compared to Smith and Smith yardsticks and evaluated on a lakewide basis. Data for local remediation chemicals would be compared to appropriate standards or guidelines used by the jurisdiction (i.e. "local standards"). Additional index sampling in these areas would be proposed if the RAP data are not adequate for the lakewide tracking purposes of this indicator. Sites would be chosen based on Remedial Action Plan information, including the nature of the use impairment, type of sediment and proximity to historical or ongoing sources of local remediation chemicals<sup>3</sup>.

DeVault, D.S, D.D. Helwig, G. Flom, D.L. Swackhammer and P. McCann. 1998 (in print). Contaminant Concentrations in Lake Trout and Sculpin from Lake Superior.

Smith, J. and I.R. Smith. 1993. Yardsticks for assessing the water quality of Lake Superior. For the Superior Work Group.

1. The nine designated zero discharge chemicals include chlordane, DDT, dieldrin, dioxin, hexachlorobenzene, mercury, octachlorostyrene, PCBs, and toxaphene

2. PAHs, alpha-BHC, cadmium, heptachlor and heptachlor epoxide

3. Local Remediation Chemicals: concentrations in sediments from Lake Superior's Areas of Concern would be compared to the applicable local standards to ensure restoration of impaired uses.

### **Illustration**

The sediment concentrations would be depicted using the standard tables and figures showing the change in concentration at different depths. Only the upper segment of the core would be compared to the yardstick or local standard. In addition, a set

of maps showing locations and concentrations of sediments in the nearshore areas and a set of maps showing sediment chemical concentrations in the Areas of Concern would serve to illustrate the indicator.

### **Limitations**

An update of this indicator with new data every two years for SOLEC may not be feasible because sediment cores may only be obtained every decade or so. However, the updates of the indicator when new information arise is applicable to past years (i.e., sediment cores will fill in the history for the previous decade). Errors in these trends should be clearly stated and tested against the null hypothesis (i.e., things are not changing).

### **Interpretation**

Progress will be determined based on whether trends of the IJC priority toxic chemicals are positive (i.e., increasing pollutant concentrations) or negative (decreasing pollutant concentrations) and by the number of chemicals which reach the virtual elimination goal.

### **Comments**

Measurements exist for many priority chemicals in the sediments of the Great Lakes system.

The desired outcome of the indicator is that the trends are negative in sign and that the concentrations reach levels which are no longer measurable by current technology.

The specific measure of the indicator is whether, as a group, the IJC priority toxic chemicals are decreasing, staying the same, or increasing in sediments at selected sites of the Great Lakes.

### **Unfinished Business**

- < Need to provide a list of the applicable IJC/PBT chemicals.
- < Need to determine if some of the IJC priority chemicals are found naturally in the environment (certain metals, etc.) If so, should the endpoint be that they are not detected above natural background levels?
- < For the presentation of the indicator “standard tables and figures” should be defined or the text modified to be more descriptive (e.g., Sediment concentrations at each site, by depth, will be displayed on a bar graph. Current detection limits will be clearly marked).

### **Relevancies**

Indicator Type: state

Environmental Compartment(s): sediments

Related Issue(s): toxics

SOLEC Grouping(s): open waters

GLWQA Annex(es): 11: Surveillance and monitoring, 12: Persistent toxic substances, 14: Contaminated sediment

IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s):

# Contaminant Exchanges Between Media: Air to Water, and Water to Sediment

## Indicator ID: 120

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### **Measure**

Estimates of air to water and water to sediment loadings of IJC priority toxic chemicals using fugacity based approaches of intermedia transport.

### **Purpose**

To measure loadings of IJC priority pollutants to the Great Lakes and to indirectly measure the potential harm these contaminants pose to human, animal and aquatic life within the Great Lakes, as well as to indirectly measure the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes..

### **Ecosystem Objective**

The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life.

### **Endpoint**

Concentrations of IJC priority chemicals within the Great Lakes are no longer measurable by current technology.

### **Features**

This indicator will track whether concentration trends of the IJC priority toxic chemicals between media are, as a group, decreasing, staying the same, or increasing in open waters over time. It combines the concentration trends in air (from indicator #117), water (from indicator #118), and sediments (from indicator #119) towards an assessment of overall trend in the loadings of these chemicals to the system. The indicator data will also demonstrate the magnitudes of the trends of the various chemicals. The magnitudes of the trends are expressed as a "half-fold time," or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals.

### **Illustration**

### **Limitations**

Though measurements of concentrations of IJC priority toxic chemicals exist for all compartments in the Great Lakes system to compute the measures of this indicator, they are not all obtained on a time scale which would allow for significant reinterpretation every two years (e.g., sediment cores may only be obtained every decade or so). However, the updates of the indicator when new information arise is applicable to past years (for example, sediment cores will fill in the history for the previous decade).

There is concern that some of the features of the loadings calculations are poorly known at present (see Comments field). This problem also exists for indicator #117, Atmospheric Deposition of Toxic Chemicals. It is important that the measures of the mass of chemical in air and in water be made at the same time.

### **Interpretation**

### **Comments**

Loadings are computed using techniques described in the "Chemicals of Concern" chapter of the Lake Superior Stage II LaMP. Intramedia transfers are computed using a fugacity based approach developed by Mackay and his co-workers (1992). The loadings approach for air to water is already expressed in a fugacity framework where the fugacity of a chemical in a medium is:

$$f = M/3 V_i Z_i$$

where  $V$  is the medium volume,  $Z$  is the fugacity capacity and  $M$  is the mass of chemical in the medium (Mackay et al., 1992). The fugacity capacities for air, water and sediments are:

$$Z_{\text{air}} = 1/RT \quad (R = \text{gas constant, } T = \text{temperature in Kelvin})$$

$$Z_{\text{water}} = 1/H \quad (H = \text{Henry's law constant})$$

$$Z_{\text{sediment}} = Z_{\text{water}} D_{\text{sediment}} N_{\text{sediment}} K_{\text{oc}}/1000$$

where

$$D_{\text{sediment}} = \text{density of the sediment}$$

$N_{\text{sediment}}$  = mass fraction in organic phase in the sediment

$K_{\text{oc}}$  = octanol-carbon partition coefficient = 0.41  $K_{\text{ow}}$  ( $K_{\text{ow}}$  is the octanol water partition coefficient).

These fugacities are used to predict the air/water, water/sediment loadings. For some chemicals, the knowledge of variables such as  $Z_{\text{water}}$  and  $K_{\text{oc}}$  or  $K_{\text{ow}}$  may be limited.

Mackay, D., W. Y. Shiu and K. C. Ma. 1992. Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals, Vol. 1, Lewis Publishers, Boca Raton, FL.

### ***Unfinished Business***

- < Need to provide an example of how the data will be presented (e.g., maps that identify sites and loadings of pollutants).
- < Need to provide information on the baseline that will be used to determine if trends are positive or negative.

### ***Relevancies***

Indicator Type: state

Environmental Compartment(s): air, water, sediments

Related Issue(s): toxics

SOLEC Grouping(s): open waters

GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances, 15: Airborne toxic substances, 17: Research and development

IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s):



# Coastal Wetland Invertebrate Community Health

## Indicator ID: 4501

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### **Measure**

Relative abundance of sensitive taxa (e.g., mayflies, caddisflies), tolerant taxa (e.g., Chironomina as a proportion of total Chironomidae abundance, Isopoda), richness of specific taxa, functional feeding groups (e.g., herbivores, detritivores, carnivores)/Index of Biotic Integrity (IBI).

### **Purpose**

To directly measure the diversity of the invertebrate community, especially aquatic insects, and to indirectly measure habitat suitability and biological integrity of Great Lakes coastal wetlands.

### **Ecosystem Objective**

Restore and maintain the diversity of the invertebrate community of Great Lakes coastal wetlands. (GLWQA Annexes 2, 11 and 13; IJC Desired Outcomes 6 and 9).

### **Endpoint**

The endpoint for this indicator will need to be established, based on a literature search of current and historical data, if available, or from data gathered from monitoring of this indicator. Data would be evaluated for patterns by lake, wetland type, and ecoregion, and then calibrated against the monitoring objectives based on the professional judgement of those with expertise in the field.

### **Features**

To restore/maintain the overall biological integrity of Great Lakes coastal wetlands, the various ecological components need to be adequately represented. The IBI will offer information on overall diversity of the invertebrate community and trends over time. The IBI is a multi-indicator, developed from a composite of specific parameters, termed "metrics," used to describe the invertebrate community, structure, function, and abundance. The IBI provides a rigorous approach that quantifies the biological condition of the invertebrate community of the Great Lakes coastal wetlands based on data from least-impacted sites that are representative of Great Lakes coastal wetlands, referred to as a reference condition.

Metrics used in the IBI to measure invertebrate community diversity will include relative abundance of sensitive and tolerant taxa, richness of specific taxa, and functional feeding groups, primarily of aquatic insects. Metrics will be scored based on how similar they are to the reference condition. The IBI will also provide a narrative characterization that provides a measure of the environmental condition and will be calibrated for regional use. The cost of monitoring for this indicator may be reduced because monitoring would apply only to the selected set of representative wetlands and may be conducted in conjunction with monitoring for other indicators.

### **Illustration**

For representative coastal wetlands, the IBI would be displayed on a map of each Lake or the basin. In addition, the invertebrate IBI score can be plotted based on a given shoreline distance to reflect patterns in Lake quality. Color-coded symbols could be used to reflect site scores for each representative Great Lakes coastal wetland. As sufficient IBI data becomes available, graphs showing trends over time would be included. A narrative explanation and analysis would also be critical to reporting on this indicator.

### **Limitations**

An invertebrate IBI is being developed for coastal wetlands that are directly connected to the Great Lakes, not for those wetlands that are only connected hydrologically via groundwater. Until the IBI is developed and tested for adequacy, the metrics to be used in developing the IBI (e.g., data on functional feeding groups) will be monitored with the intent that the IBI can be calculated in the future using previously collected monitoring data.

### **Interpretation**

This indicator would be evaluated as part of an overall analysis of biological communities of Great Lakes coastal wetlands.

### **Comments**

The presence, diversity and abundance of invertebrates tend to correlate with factors such as water depth, vegetation, and sediment type. Because such localized conditions influence the invertebrate community present in each wetland, a sufficient number of representative wetlands will be needed to characterize each lake basin adequately.

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected.

### **Unfinished Business**

**Relevancies**

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): habitat

SOLEC Grouping(s): coastal wetlands

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13:  
Pollution from non-point sources

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

# Coastal Wetland Fish Community Health

## Indicator ID: 4502

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### **Measure**

Index of Biotic Integrity (IBI)

### **Purpose**

To directly measure fish community diversity and indirectly measure habitat suitability for Great Lakes coastal wetland fish communities.

### **Ecosystem Objective**

Restore and maintain the diversity of the fish community of Great Lakes coastal wetlands. (GLWQA Annexes 2, 11, and 13; IJC Desired Outcomes 6 and 9)

### **Endpoint**

An endpoint for this indicator will need to be established, based on a literature search of current and historical data, if available, or from data gathered from monitoring of this indicator. Data would be evaluated for patterns by lake, wetland type, and ecoregion, and then calibrated against the monitoring objectives based on the professional judgement of those with expertise in the field.

### **Features**

The IBI provides a rigorous approach to quantify the biological condition of fish communities within the Great Lakes. It is based on reference conditions and is developed from a composite of specific measures used to describe fish community, structure, function, individual health, and abundance. Specific parameters, termed "metrics," are scored based on how similar they are to the reference condition. These parameters will include species richness and abundance, percent exotic species, and percent phytophils. The IBI will also provide a narrative characterization that provides a measure of the environmental condition and will be calibrated for regional use.

### **Illustration**

For representative coastal wetlands, the IBI would be displayed on a map of each Lake or the basin. In addition, the IBI score can be plotted based on a given shoreline distance to reflect patterns in Lake quality. Color-coded symbols could be used to reflect site scores for each representative Great Lake coastal wetland. As sufficient IBI data becomes available, graphs showing trends over time would be included. A narrative explanation and analysis would also be critical to reporting on this indicator.

### **Limitations**

Until the IBI is developed and tested for adequacy, the metrics to be used in developing the IBI will be monitored with the intent that the IBI can be calculated in the future using previously collected monitoring data.

### **Interpretation**

This indicator would be evaluated as part of an overall analysis of biological communities of Great Lakes coastal wetlands and nearshore aquatic systems.

### **Comments**

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s): fish

Related Issue(s): habitat

SOLEC Grouping(s): coastal wetlands

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

## Deformities/Eroded Fins/Lesions/Tumors (DELT) in Coastal Wetland Fish

### Indicator ID: 4503

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#### **Measure**

Numbers and percent of DELT in coastal wetland fish.

#### **Purpose**

To directly measure the incidence of DELT in fish of Great Lakes coastal wetlands and to indirectly measure the ecosystem health of Great Lakes coastal wetlands.

#### **Ecosystem Objective**

Restore the health of fish of Great Lakes coastal wetlands. (GLWQA Annexes 2, 11, 12, and 17; IJC Desired Outcome 7)

#### **Endpoint**

The incidence DELT should be less than 0.1% of site catch to attain reference conditions (Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity and its rational. Illinois Natural History Survey Publication 5).

#### **Features**

DELT anomalies reflect the lowest levels of biological integrity. High incidence of DELT is a reflection of degraded conditions. Fish collected from a site would be inspected for gross external presence of DELT. Fish having DELT would be counted and the percentage of DELT anomalies would be composited over all species and individuals in the total catch.

#### **Illustration**

For each Lake, a graph will display the percentage of DELT showing annual mean and 95% confidence intervals for total catch. This indicator can be displayed as either a bar chart or box-and-whisker plot.

#### **Limitations**

There are almost no additional monitoring costs associated with this indicator. Field crews collecting fish community data would be required to carefully inspect each fish for the presence of DELT anomalies, which will add handling time. The indicator is closely linked to the overall level of contaminants that contribute either additively or synergistically to reduce biological integrity. Presence of DELT does not always necessarily reflect site conditions since some fish species may be mobile. However, the majority of species remain in select areas for portions of the life cycle and will show signs of any effects.

#### **Interpretation**

Where DELT exceeds the endpoint of 0.1%, proximity to point source discharges and other contaminant sources can be evaluated as a link to causes and effects.

#### **Comments**

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The Biodiversity Investment Areas paper from SOLEC '98 identifies these sets of representative wetlands that adequately characterizes each lake basin. This indicator may also apply to nearshore aquatic areas.

#### **Unfinished Business**

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s): fish

Related Issue(s): toxics

SOLEC Grouping(s): coastal wetlands

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development

IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s): 5: Bird or animal deformities or reproductive problems

# Amphibian Diversity and Abundance in Coastal Wetlands

## Indicator ID: 4504

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### **Measure**

Species composition and relative abundance of calling frogs and toads, based on evening surveys using protocol developed for the Marsh Monitoring Program (MMP) or modification of MMP protocol.

### **Purpose**

To directly measure the species composition and relative abundance of frogs and toads and to indirectly measure the condition of coastal wetland habitat as it relates to the health of this ecologically important component of wetland communities.

### **Ecosystem Objective**

Restore and maintain the diversity of Great Lakes coastal wetland amphibian communities. Breeding populations of amphibian species across their historical range should be sufficient to ensure continued success of each species. (GLWQA Annexes 11 and 13, IJC Desired Outcomes 6 and 9)

### **Endpoint**

An endpoint will need to be established, based on a literature search of current and historical data, if available, or from data gathered from monitoring of this indicator. Data on amphibian diversity and abundance would be evaluated for patterns by lake, wetland type, and ecoregion, and then calibrated against the monitoring objectives based on the professional judgement of those with expertise in the field.

### **Features**

To restore/maintain the overall biological integrity of Great Lakes coastal wetlands, the various ecological components need to be addressed adequately represented. This indicator will track trends in Great Lakes coastal wetland amphibian diversity and relative abundance over time.

### **Illustration**

For representative coastal wetlands along each of the Lakes, the monitoring results could be graphically displayed. As sufficient data become available, graphs showing trends over time would be included. A narrative explanation and analysis would also be critical to reporting on this indicator.

### **Limitations**

This indicator focuses on frogs and toads because they are more readily censused than other amphibians. Other amphibian species, such as salamanders, would not be censused at all. Nonetheless, monitoring results for the species surveyed (i.e., frogs and toads) may provide an indication of habitat suitability for other amphibians dependent on coastal wetlands. The relationships among calling codes recorded during surveys, amphibian chorus size, and local population size need to be studied. This validation work is necessary for extrapolations from call code surveys to population sizes.

### **Interpretation**

Amphibian populations naturally fluctuate over time; therefore, this indicator would be evaluated as part of an overall analysis of biological communities of Great Lakes coastal wetlands. Many amphibian species are associated with wetlands for only a portion of their life cycle. Periodically, more rigorous studies may be needed at some sites to relate trends in species occurrence or relative abundance to environmental factors. Adequate upland areas adjacent to coastal wetlands are important to amphibians, and indicators of suitable, adjacent upland areas also need to be considered when assessing amphibian population trends. Species of particular interest are Northern Leopard Frogs and Bullfrogs. Green Frogs seem to be replacing Bullfrogs in many areas, therefore, the ratio of Green Frogs to Bullfrogs should be monitored.

### **Comments**

Properly trained volunteers currently conduct monitoring and all data are subject to the quality assurance program. Additional coastal wetlands could be selected if additional volunteers are available to conduct monitoring. Any additional wetlands would have to be selected based on criteria to be established. Available data on historical and current presence/ abundance of amphibians should be collected to supplement monitoring data. Monitoring programs/protocols other than the MMP exist, such as backyard survey and road-call count, although they do not specifically focus on coastal wetlands.

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected.

Any deformities should be noted and shared with the monitoring program for deformities.

### **Unfinished Business**

**Relevancies**

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): habitat

SOLEC Grouping(s): coastal wetlands

GLWQA Annex(es): 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

# Contaminants in Snapping Turtle Eggs

## Indicator ID: 4506

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### **Measure**

Concentrations of organochlorine chemicals and mercury in Snapping Turtle eggs.

### **Purpose**

To directly measure the accumulation of organochlorine chemicals and mercury in Snapping Turtle eggs in order to assess the effects of contaminants on snapping turtle embryonic development. This information will indirectly measure the contamination in the food web of Great Lakes coastal wetlands.

### **Ecosystem Objective**

Snapping Turtle populations in Great Lakes coastal wetlands and populations observed at a clean inland reference site, such as Algonquin Provincial Park, Ontario, should not exhibit significant differences in hatching success and abnormality rates. (GLWQA Annexes 1, 2, 11, and 12; IJC Desired Outcome 5)

### **Endpoint**

a) Mean wet weight concentrations in Snapping Turtle eggs should not exceed\*:

Toxic Equivalents= 158.3 ug/g  
Total polychlorinated biphenyl (PCB)= 0.338 ug/g  
Total polychlorinated dibenzo dioxins (PCDD)= 1.0 pg/g  
Total polychlorinated dibenzo furans (PCDF)= 3.0 pg/g  
pp'DDE (metabolite of DDT)= 0.05 ug/g  
mirex= 0.0014 ug/g

b) Mean wet weight concentrations in plasma from Snapping Turtle eggs should not exceed\*:

Total PCB= 17.8 ng/g  
Total PCDD= 7.0 pg/g  
Total PCDF= 4.2 pg/g  
pp'DDE= 1.0 ng/g  
mirex= 0.4 ng/g

\*See Comments" for information on the derivation of these tentative concentrations for use as endpoints.

### **Features**

Snapping Turtles are long-lived, top predators that bioaccumulate contaminants. Their embryonic and sexual development appear to be sensitive to organochlorine chemicals. Given these characteristics, the Snapping Turtle is useful in monitoring trends in contaminants levels within specific wetlands. Variations in diet among Snapping Turtle populations can influence the degree of contamination in the population. Where large contaminated carp are the predominant species in the fish community, and a primary source of food, the contaminant exposure in Snapping Turtles will likely be higher and persist for longer periods. Some Snapping Turtle populations consume smaller fish in a more diverse fish community where the turnover rate of contaminants is faster in the fish population. Hence, some sites would show more rapid changes in contaminant trends.

### **Illustration**

Mean abnormality rate at the uncontaminated reference site (e.g., Algonquin Provincial Park) superimposed over rates at representative sites from the Lakes and connecting channels. This would be presented as a bar graph showing sites and abnormality rates, along with the mean abnormality rate for the reference site as a comparison.

### **Limitations**

This indicator requires labor-intensive sampling (2 weeks in June) and expensive analyses. The monitoring for this indicator focuses only on persistent chemicals, and therefore does not illustrate trends in other types of contaminants that may be present in Great Lakes coastal wetlands.

### **Interpretation**

Contamination levels and developmental effects observed in Snapping Turtles at reference sites, and other sites throughout the Great Lakes, would provide the context needed to interpret this indicator. Since variation in diet among Snapping Turtle populations can influence contaminant levels, additional information on fish diversity at the study sites will help to interpret the trends illustrated by this indicator.

### **Comments**

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected.

The concentrations provided as endpoints for this indicator serve as tentative concentrations which should not be exceeded to ensure that the hatching success and hatchling deformity rates do not significantly exceed those at the examined inland, non-contaminated reference sites.

The mean wet weight concentration in Snapping Turtle eggs provided as endpoints are concentrations found in eggs from Big Creek Marsh, Lake Erie which showed no significant difference in hatching rates and deformity rates as compared to Lake Sasajewun, Algonquin Provincial Park, an inland lake in Ontario.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): biota

Related Issue(s): toxics

SOLEC Grouping(s): coastal wetlands

GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances

IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s):



# Wetland-Dependent Bird Diversity and Abundance

## Indicator ID: 4507

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### **Measure**

Species composition and relative abundance of wetland-dependent birds, based on evening surveys using protocol developed for Marsh Monitoring Program (MMP) or modification of the MMP protocol.

### **Purpose**

To directly measure the wetland bird species composition and relative abundance and to indirectly measure the condition of coastal wetland habitat as it relates to the health of this ecologically and culturally important component of wetland communities.

### **Ecosystem Objective**

Restore and maintain the diversity of Great Lakes coastal wetland bird communities. Breeding populations of bird species across their historical range should be sufficient to ensure continued success of each species. (GLWQA Annexes 2, 11, and 13; IJC Desired Outcomes 6 and 9)

### **Endpoint**

An endpoint will need to be established, based on a literature search of current and historical data, if available, or from data gathered from monitoring of this indicator. Data on the species composition and relative abundance of wetland-dependent birds would be evaluated for patterns by lake, wetland type, and ecoregion, and then calibrated against the monitoring objectives based on the professional judgement of those with expertise in the field.

### **Features**

This indicator will offer information on wetland bird diversity and abundance trends over time. It will provide a temporal measure of Great Lakes coastal wetland bird communities and may be made compatible with the Marsh Monitoring Program, an ongoing wetland monitoring program initiated throughout the Great Lakes basin in 1995.

### **Illustration**

For representative coastal wetlands along each of the Lakes, trends in relative abundance for individual species could be graphically displayed. Indices, tables and diagrams will be used to depict community species composition characteristics.

### **Limitations**

A rigorously tested index of the relationships between wetland bird community composition and critical environmental factors (i.e. an Index of Biotic Integrity (IBI) for birds) is the preferable approach to community-based indicators, but has not yet been developed for wetland birds. The development of such an IBI should be an important priority. The IBI should be able to take advantage of the information on species occurrence and relative abundance currently collected through the MMP.

### **Interpretation**

Both regional and local populations naturally fluctuate over time, therefore, several years of monitoring data will be required to detect all but the most dramatic trends. Interpretation of this indicator will be most effective if coupled with patterns observed in other indicators (e.g., indicator # 4501, Invertebrate Community Health; indicator # 4510, Wetland Area by Type).

Wetland birds are highly mobile and most are dependent on wetlands for only portions of their life cycle. Temporal trends in local bird populations can be influenced by factors external to wetlands on the wintering grounds, during migration, or on the breeding grounds. For this reason, intensive work will be required to identify site- and region-specific impacts to bird breeding productivity and survivorship. These intensive studies are particularly important in the absence of a well-tested IBI.

### **Comments**

With proper training and quality assurance, volunteers could conduct wetland bird surveys, allowing a relatively modest investment in SOLEC monitoring and analysis. This indicator would apply most directly to the selected representative wetland sites, but could be made to complement, and draw a regional context from, existing wetland monitoring efforts in both coastal and inland sites in the Great Lakes basin. Wetland birds are important from both a cultural and ecological perspective. Monitoring of wetland-dependent bird species of conservation concern (e.g. Black Tern, Least Bittern, King Rail) should receive special attention during protocol development.

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected.

### **Unfinished Business**

**Relevancies**

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): habitat

SOLEC Grouping(s): coastal wetlands

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13:  
Pollution from non-point sources

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

## Coastal Wetland Area by Type

### Indicator ID: 4510

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#### **Measure**

Areal extent of coastal wetlands by type as a range (e.g., dry year/low water level area versus wet year/ high water level area).

#### **Purpose**

To measure periodic changes in area (particularly losses) of coastal wetland types, taking into account natural variations.

#### **Ecosystem Objective**

Reverse the trend toward loss of Great Lakes coastal wetlands, ensuring adequate representation of wetland types across their historical range. (GLWQA Annexes 2,11, and 13; IJC Desired Outcomes 6 and 9)

#### **Endpoint**

No net loss of coastal wetlands due to human actions and, in the future, a net gain to coastal wetlands due to restoration activities.

#### **Features**

The wetland area should be reported as a basin total and by type (based on geomorphology, vegetation, water regime, size class, degradation), putting the baseline numbers into a historical perspective. Monitoring of each specific wetland type provides a baseline for other examples of that wetland type. The monitoring must be conducted over an entire Great Lakes water level cycle to obtain meaningful baseline data.

#### **Illustration**

For each wetland type, graphs could show the areal extent of specific wetland types as they change relative to water level and over time.

#### **Limitations**

Although not inexpensive, remote sensing, with limited ground checking of zone width, would be the most cost-effective method of monitoring this indicator. The costs might be partially offset if other SOLEC indicators are also monitored using remote sensing.

The extent of each coastal wetland type varies with Great Lakes water level fluctuations. Monitoring must be repeated throughout the Great Lakes water level fluctuation cycle. No one is currently doing this on a regular basis. Conducting the monitoring and detecting human-induced change in an area may not be feasible in the two-year time frame of SOLEC.

Wetland area change caused by human actions may be difficult to measure because (a) natural water level fluctuation can have a dramatic effect on area by type and (b) a historic 'original size' by type for each water level regime is difficult to establish.

#### **Interpretation**

This indicator needs to be evaluated in terms of both wetland quality and extent. For example, wetlands may decrease due to lack of Great Lakes water level fluctuation, as on Lake Ontario, and the quality and value of the wetland to wildlife/fish may be reduced tremendously. When interpreting the data, the other coastal wetland indicators that evaluate wetland quality need to be considered. For measuring the variable in a most superficial way, the extent of the wetland remaining could be estimated to the nearest 10% and then divided by 10, providing a score of 1-10. For example, a wetland type that remains at roughly 80% of its original size within a particular water level regime would have a score of  $80/10=8$ .

#### **Comments**

The wetland area measured would include the data from indicator #4511, Gain in Restored Wetland Area by Type.

#### **Unfinished Business**

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s): land

Related Issue(s): habitat

SOLEC Grouping(s): coastal wetlands

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

# Gain in Restored Coastal Wetland Area by Type

## Indicator ID: 4511

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### **Measure**

Gain in restored wetland area by type.

### **Purpose**

To measure the gain in restored wetland area and the success of conservation/rehabilitation efforts.

### **Ecosystem Objective**

Sufficient gain in restored wetland area to ensure adequate representation of coastal wetlands by type across their historical range. (GLWQA Annexes 2, 11, and 13; IJC Desired Outcomes 6 and 9)

### **Endpoint**

The endpoint for this indicator needs to be defined and could be as simple as defining a certain amount of Great Lakes areas that should be classified as wetland. There should be enough gain in wetland area to offset any losses to ensure no net loss; however, opportunities for wetland gain may be limited by lack of available sites. Also, the endpoint should consider wetland quality including zones of vegetation and desired species.

### **Features**

This indicator measures additional restored wetland area, not enhancement of existing wetland area. When evaluating this indicator, wetland quality, not just total restored area needs to be considered. High quality examples of each wetland type, based on geomorphology and climatic setting, should be used to define the expected zones of vegetation, sediment characteristics, and plant species in restored wetland. Also, wildlife use, based on baseline high quality wetlands, could be used to evaluate the success of the wetland restoration. Other coastal wetland indicators should be used to help interpret wetland quality.

### **Illustration**

A graph displaying the amount of gained/restored wetland area by type over time.

### **Limitations**

The gain in restored wetland area does not necessarily reflect the quality of the wetland. Also, lack of available sites for restoration would be a limitation.

Data quality may vary because data will be submitted from a number of agencies. Also, because of multi-agency partnerships in most restoration projects, it is crucial to ensure that restored areas are counted only once when agencies submit data from the same project.

Wetland area change caused by human actions may be difficult to measure because (a) natural water level fluctuation can have a dramatic effect on area by type and (b) a historic 'original size' by type for each water level regime is difficult to establish.

### **Interpretation**

By looking at both indicator #4510, Wetland Area by Type, and the gain in restored area within a particular water level regime, it will be possible to determine whether the no net loss goal is being met, or being surpassed with additional gains. Further investigation or incorporation of historical data could be important for Lakes Erie and Ontario and the St. Lawrence River. For many of the wetland types characterizing the Great Lakes shoreline, baseline data for high quality examples exist for both the typical zonation, relation to water depth, and typical plant species of each zone. Baseline data for Lakes Erie and Ontario and the St. Lawrence River are less reliable because of the high level of wetland degradation. In Lake Ontario and the St. Lawrence River, water level control/manipulation has altered the species composition in even the least disturbed wetlands.

### **Comments**

Gain in wetland area will be determined using data reported by agencies that track wetlands restoration, and confirmed by remote sensing. This will allow gain, not just enhancement of existing wetland, to be tracked. Agencies will need to provide documentation about the location of restoration projects and track restoration (i.e. true gain in area) versus enhancement (i.e. modifications to existing area).

### **Unfinished Business**

### **Relevancies**

Indicator Type: state

Environmental Compartment(s): land

Related Issue(s): habitat

SOLEC Grouping(s): coastal wetlands

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13:  
Pollution from non-point sources

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

# Presence, Abundance & Expansion of Invasive Plants

## Indicator ID: 4513

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### **Measure**

Presence, abundance, & expansion of invasive plants, such as flowering rush, great hairy willow-herb, common frogbit, yellow iris, purple loosestrife, Eurasian water milfoil, curly pondweed, cattail, Phalaris, and Phragmites.

### **Purpose**

To measure the decline of vegetative diversity as characterized by the increase in the presence, abundance, and expansion of invasive plants and to provide a surrogate measure of coastal wetland quality because the presence of invasive plant species generally indicates the level of coastal manipulation or input of sediments which cause wetland degradation.

### **Ecosystem Objective**

Coastal wetlands throughout the Great Lakes basin should contain low numbers of invasive plant species with low levels of coverage. (GLWQA Annexes 2, 11, and 13; IJC Desired Outcome 6)

### **Endpoint**

Species of invasive plants and the degree of aerial coverage associated with each species, vary by wetland type, lake, region, and latitude, due to differences in geomorphic and climatic conditions. Specific coverage values would have to be established for each wetland type and for each invasive plant species.

### **Features**

Two considerations in assessing the condition of coastal wetlands are quantity and quality. The areal extent of a wetland can be large, but the same wetland can be highly degraded or modified by the dominance of invasive plant species. Similarly, wetland restoration may result in extensive wetlands, but dominance by invasive plant species can reduce the value of such wetlands considerably. This indicator will track the quality of coastal wetlands by assessing the biodiversity of wetland vegetation over time.

### **Illustration**

Graphs will display the of number of invasive plant species and percent coverage over time. To illustrate this indicator, maps will show how the range of invasive plant species has expanded over time.

### **Limitations**

The presence, abundance, and expansion of most invasive plant species cannot be evaluated solely on the basis of aerial photography or satellite imagery, thus requiring some field visits to locate certain species and monitor their expansion. Once documented, aerial photography may be used to monitor the patch size of some invasive plant species. Certain invasive plant species have been adequately studied, and their detrimental effect on the ecosystem and their ability to expand into certain habitats has been documented. Other invasive plant species have not yet been adequately evaluated, therefore, little is known about their effect on the ecosystem or their ability to expand into certain habitats.

### **Interpretation**

A ranking could be developed based on a combined score of 1) the number of invasive plant species and 2) the coverage value of coastal wetlands dominated by invasive plant species.

### **Comments**

This indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies these sets of representative wetlands that adequately characterizes each lake basin.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): habitat

SOLEC Grouping(s): coastal wetlands, nearshore terrestrial

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

# Sediment Flowing into Coastal Wetlands

## Indicator ID: 4516

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### **Measure**

Suspended Sediment Unit Area Load (tonnes/km<sup>2</sup> of upstream watershed) for a representative set of existing monitoring sites just upstream of coastal wetlands.

### **Purpose**

To indicate sediment load to coastal wetlands and its potential impact on wetland health.

### **Ecosystem Objective**

To maintain and restore healthy coastal wetlands which are highly dependent on appropriate sediment loads. (GLWQA Annexes 1, 2, 11, and 13; IJC Desired Outcomes 6 and 9)

### **Endpoint**

Wetlands require some sediment to maintain barriers and elevation against scour etc., so the reference value is not zero. A desired endpoint can be set from unit area loads of representative wetlands considered to have low sedimentation problems.

### **Features**

Sediment load is critical to habitat health and is one of the major wetland stressors. Sites throughout the basin can be chosen to represent inflow to individual wetlands and it is possible that there is enough existing monitoring to represent the basin. The data are already collected, analyzed, and maintained comparably in both countries. There is fairly high variability among the data because sediment loads are directly related to flow, which varies depending on precipitation events. Sediment loads are also dependent upon agricultural land management practices and land use. This indicator links to other wetland stressor indicators that have similar causes, including #4560, Nitrates and Total Phosphorus into Coastal Wetlands, and indicator #4519, Number of Extreme Storms. Sediment load itself affects the Wetland State/Response Indicators including those associated with area by type, invasive plants and wildlife.

### **Illustration**

This indicator could be displayed graphically as tonnes/km<sup>2</sup> (y axis) versus time (x axis). The desired reference point or endpoint could be indicated on the y axis and across the graph.

### **Limitations**

The indicator is developed from flow measurements using stream-specific and regularly updated relationships of flow and sediments.

### **Interpretation**

Interpretation will be based on the magnitude of the difference of the monitoring site loads from the reference load. The reference load will be scored as 10. The greater the difference in the monitored load, the lower the score. Additional information that could help interpret reasons for sediment load include: weather, conservation practices data, and upstream reservoirs. Data for percentage of silt and clay are also available and can help interpret associated contaminants and whether material is likely to settle out or not.

### **Comments**

This is a clearly understood indicator to which both development and agriculture industries can relate. Excess sediment is of concern not only for its physical smothering, in-filling and light obstruction properties but also for other harmful contaminants it can carry.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): water, sediments

Related Issue(s): habitat

SOLEC Grouping(s): nearshore waters, coastal wetlands

GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

# Nitrates and Total Phosphorus Into Coastal Wetlands

## Indicator ID: 4860

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### **Measure**

Concentration of nitrate and of total phosphorus just upstream from, or in, a set of Great Lakes coastal wetlands.

### **Purpose**

To directly measure nitrate and total phosphorus levels in or flowing into Great Lakes coastal wetlands to determine instances of non-excessive nutrient levels in the wetlands, and to indirectly measure trends resulting from human influence on nutrient levels, as excess nutrients can be detrimental to the health of coastal wetlands.

### **Ecosystem Objective**

Maintenance and restoration of more natural levels of nutrients to maximize: species and community diversity, wetland integrity and wetland values. (GLWQA Annexes 3, 11, and 13; IJC Desired Outcomes 6 and 9)

### **Endpoint**

In the growing season, at least one instance of < 0.5 mg/l nitrate and < 0.03 mg/l total phosphorus.

### **Features**

This indicator will assess the concentrations of nitrate and total phosphorus found in and entering Great Lakes coastal wetlands. These are the major nutrients affecting coastal wetlands. Data for this indicator will be collected from the following locations: 1) existing closest stream monitoring sites within 5 km upstream of a coastal wetland (within 10 km upstream if on the Canadian Shield); 2) existing monitoring for Long Range Transport of Air Pollutants (LRTAP) at stations nearest the coastal wetland sites with stream monitoring stations; and 3) proposed in situ monitoring of a representative set of coastal wetlands. Past trends can be constructed using historical stream data, which exists for many years.

The indicator will be updated on an annual basis, as new data are available. Stream sampling data are often collected on the order of 1 sample per month. Concentrations may vary with seasons and events but choice of presence/absence type indicator during the growing season greatly reduces variability. This indicator links to other coastal wetland indicators that assess wildlife affected by eutrophication or reduced habitat diversity (e.g., #4501, Coastal Wetland Invertebrate Community Health; #4502, Coastal Wetland Fish Community Health; #4504, Amphibian Diversity and Abundance in Coastal Wetlands), as well as indicator #4510, Coastal Wetland Area by Type, and indicator #4513, Presence, Abundance and Expansion of Invasive Plants. The in situ sampling piggy-backed on wetland visits proposed for other indicators and will have relatively low associated lab costs.

### **Illustration**

This indicator will be presented using a graph with y axis as % of sites with at least 1 instance of both <0.5 mg/l nitrate and <0.03 mg/l total phosphorus from May to July, and x axis as time in years. Percentage reaching the endpoint can also be recorded for each of the set of upstream samples (with airborne contribution (LRTAP) concentrations added) and the set of in situ samples in case their trends differ.

### **Limitations**

Low incremental cost assumes (1) no major downsizing of the stream water quality monitoring network, and (2) on-site wetland visits by biologists monitoring other indicators. Total phosphorus has an official standard; nitrate does not. Variation within each wetland will require a general protocol for such factors as storm event avoidance and grab sample location.

### **Interpretation**

The higher percentage of sampled wetlands and streams reaching the endpoint (at least one instance of both < 0.5 mg/l nitrate and <0.03 mg/l total phosphorus from May through to July), the better. A ranking system of 0 to 10 can be used to interpret this indicator, with 0 for no stations reaching the endpoint and 10 for all (100%) stations reaching the endpoint.

Analysis of this indicator must consider recent data from monitoring stations dropped since the previous year's monitoring. For example, if dropped stations were all high water quality, then their omission, rather than just pollution levels, affects the trend in percentage reaching the endpoint.

### **Comments**

In nutrient over-enriched wetlands, a few species out-compete many others reducing biological and social values. One instance of low concentration indicates the site is capable of non-excessive nutrient levels and allows the indicator to avoid (1) the confusion imposed by the high variability in concentration which often occurs among monthly samples, and (2) the need for many more samples to fully assess nutrient level regimes.

### **Unfinished Business**



**Relevancies**

Indicator Type: pressure

Environmental Compartment(s): water

Related Issue(s): nutrients

SOLEC Grouping(s): coastal wetlands

GLWQA Annex(es): 3: Control of phosphorus, 11: Surveillance and monitoring

IJC Desired Outcome(s): 8: Absence of excess phosphorus

GLFC Objective(s):

Beneficial Use Impairment(s): 8: Eutrophication or undesirable algae

## Water Level Fluctuations

### Indicator ID: 4861

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**Note:** *This indicator is both a Coastal Wetland and Nearshore Terrestrial indicator*

#### **Measure**

For each lake: 1) Mean lake level; 2) Lake-wide annual range in monthly averages; 3) Lake-wide seasonal peak (days after January 1); 4) Lake-wide seasonal minimum (days after September 1); and 5) Elevation Difference between Upper and Lower Emergent Vegetation Extent based on Water Level model (Painter & Keddy, 1992).

#### **Purpose**

To directly measure lake level trends that significantly affect components of wetland ecosystems, and to indirectly measure the effect of water level regulation on emergent wetland extent.

#### **Ecosystem Objective**

To maintain and restore healthy coastal wetlands whose existence and integrity depend on naturally fluctuating water levels (GLWQA Annexes 2, 11, and 17; IJC Desired Outcomes 6 and 9).

#### **Endpoint**

The endpoint for this indicator is based on four historic ranges (i.e., data exceeded 0-25%, 25-50%, 50-75%, and 75-100% of the years examined) for each measure per lake. All years of historical data from 1918 to 1959 for Lake Ontario, and from 1918 to 1980 for all other lakes, will be used to set the historic ranges. The endpoint is reached if in the previous 20 years, distribution of data is fairly evenly distributed among the four historic ranges. The endpoint for water level regulation effects is the elevation difference between upper and lower emergent vegetation extent, calculated by application of the Painter and Keddy model to water levels in Lakes Ontario and Superior under a “no regulation” scenario.

#### **Features**

Lake levels have a major influence on undiked coastal wetlands and are basic to any analysis of wetland change trends. This indicator uses existing annual summaries of lake and basin-wide water level fluctuations based on daily data. Natural variability will occur in each measure, but will be accounted for in the interpretation method. Yearly data can vary and should be reviewed whenever data for other wetland indicators are collected. Interpretation into the score of 10 (see Interpretation), however, will show far less variability and may be required only every second or third SOLEC cycle. This indicator links to indicator #4510 Coastal Wetland Area by Type, and all wildlife indicators. The data for this indicator are already collected, standardized, easily available and analyzed.

#### **Illustration**

One graph per lake of “Correspondence of Previous 20 Years of Water Levels With Historical Distribution” on the y-axis with the x-axis as time in years. Lakes Ontario and Superior will also have a graph of “Effect of Regulation on Extent of Emergent Vegetation Elevation”, which will be the difference between pre- and post-regulation modeled values each year. Lakes Michigan and Huron will be illustrated on one graph.

#### **Limitations**

Some analysis is required to set historical reference ranges and to calculate emergent vegetation elevation difference. The indicator shows changes from historic distribution of levels but cannot distinguish if changes are due to natural climatic variability or human-induced climate change. The emergent elevations are based on a model using lake level data but not direct field measurements of vegetation extent.

#### **Interpretation**

If previous 20 years of data are distributed evenly across the historical range for a measure (i.e., within historical high and low values AND distributed reasonably evenly among the 4 historical ranges), the trend can be interpreted as “good.” If a year is beyond high or low historical value OR distribution is becoming highly skewed from a fairly even distribution among the 4 historical ranges, the trend can be interpreted as “bad.”

A ranking system of 0 to 10 can be used to determine the trend of the overall indicator (i.e., an aggregate of all five measures). Each of 5 parameters for each lake will receive a score of 0, 1, or 2, depending on how well the previous 20 years of data fit the historical ranges. The total of the scores for the 5 parameters identified under Measure above provides a lake score (maximum of 10). An average of the 4 lakes scores could provide a basin-wide score. The four lakes are Superior, Michigan/Huron, Erie and Ontario. The y axis of the “Effect of Regulation” graphs will be scaled so larger effects score lower; no effect scores 10.

Lake St. Clair is omitted from the basin-wide score since ice jams in the Detroit and St. Clair Rivers can greatly affect ranges and extreme levels. For the same reason St. Clair indicators are restricted to the average level and elevation differences.

### **Comments**

Water levels are important to the public. The importance to wetland integrity, however, of natural level fluctuations is less widely appreciated and use of modeled elevations of emergents, historical ranges and one index for all parameters and lakes may be difficult for public understanding.

Painter, Scott and Paul Keddy, 1992. Conceptual Emergent Marsh Response to Water Level Regulation. National Water Research Institute, Environment Canada, Burlington Ontario.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): water, land

Related Issue(s): habitat, climate change

SOLEC Grouping(s): coastal wetlands, nearshore terrestrial

GLWQA Annex(es): 11: Surveillance and monitoring, 17: Research and development

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

# Habitat Adjacent to Coastal Wetlands

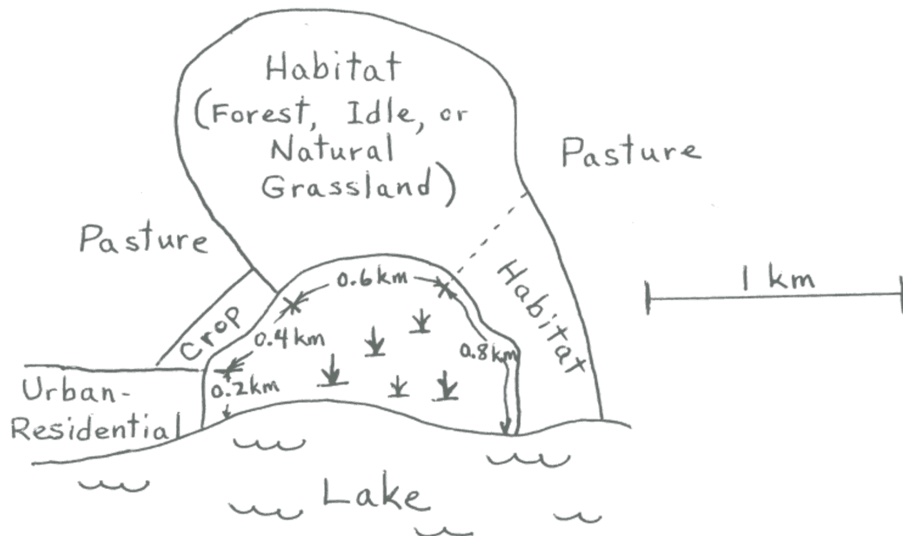
## Indicator ID: 7055

### Measure

Land use adjacent to a representative set of coastal wetlands, measured as a weighted score determined by multiplying the wetland perimeter (km) in each land use by an associated weighting factor and dividing by the total upland perimeter (km) of the wetland. Weighting factors depend on the width of habitat (wooded, idle or natural grassland cover) directly abutting the wetland and on the land use adjacent to that habitat, as shown below:

### Habitat Width Adjacent to Wetland

| Habitat Width Adjacent to Wetland | Land Use Adjacent to Habitat |          |             |
|-----------------------------------|------------------------------|----------|-------------|
|                                   | Urban/Residential            | Row Crop | Hay/Pasture |
| >750 m                            | 1                            | 1        | 1           |
| 250 - 750 m                       | 0.25                         | 0.5      | 0.8         |
| 50 - 250 m                        | 0.1                          | 0.2      | 0.5         |
| 20 - 50 m                         | 0.05                         | 0.1      | 0.25        |
| <20 m                             | -1.0                         | -0.5     | -0.2        |



$$\text{Score} = \frac{((0.2 \text{ km})(-1) + (0.4 \text{ km})(-0.5) + (0.6 \text{ km})(1) + (0.8 \text{ km})(0.8))}{(0.2 \text{ km}) + (0.4 \text{ km}) + (0.6 \text{ km}) + (0.8 \text{ km})}$$

$$= \frac{(-0.2 \text{ km}) + (-0.2 \text{ km}) + (0.6 \text{ km}) + (0.64 \text{ km})}{2.0 \text{ km}} = 0.42$$

### Purpose

To indirectly measure 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.

### Ecosystem Objective

To maintain and restore healthy coastal wetlands and associated diverse wildlife populations which require adequate adjoining upland habitat (GLWQA Annexes 11 and 13; IJC Desired Outcome 6 and 9).

### Endpoint

Score for Habitat Adjacent to Coastal Wetlands = 1 (corresponding to all wetlands with adjacent habitat >750 m).

### **Features**

This is an indicator of off-site influence, and assesses the effects of land uses adjacent to coastal wetlands. It is potentially linked to all of the Coastal Wetland State/Response indicators. Although related to indicator #8132, Nearshore Land Use Intensity, and to indicator #8136, Nearshore Natural Land Cover, its specificity to wetlands makes it much more relevant to wetland health. It will show steady trends rather than high variability.

### **Illustration**

A graph will be displayed with x-axis as years and y-axis as adjacent habitat ranging from a worst case (all wetlands with adjacent urban uses) of -1 to a best case (all wetlands with > 750 m of adjacent habitat) of 1.

### **Limitations**

This indicator is a direct measure of habitat for only a subset of coastal wetlands. This subset should represent wetland types, adjacent habitat, and land uses. Weighting factors are best estimates rather than based on precise science, but can easily be amended and applied to past data. Like several wetland indicators, it depends on availability and utility of remote sensing for the representative set. Interpretation, although straightforward, will take some time.

### **Interpretation**

The lower the weighted average, the worse the ranking.

### **Comments**

Among coastal ecosystems, the integrity of coastal wetlands is particularly dependent on adjoining habitat. Many wetland biota need non-wetland habitat for part of their life cycle, with varying area and distance requirements. The quality (e.g., disturbance, surface water quality) of adjoining habitat is in turn influenced by its abutting land use. This indicator uses simple scores to quantitatively rank these relationships.

This Indicator would apply to a selected set of representative wetlands for each of the coastal reaches of the Great Lakes. The SOLEC '98 Biodiversity Investment Areas paper on Coastal Wetland Ecosystems identifies the ecoreaches from which representative wetlands will be selected. Also, each site can be individually scored for local interest.

### **Unfinished Business**

#### **Sorting**

Indicator Type: state

Environmental Compartment(s): land

Related Issue(s): habitat

SOLEC Grouping(s): coastal wetlands, land use

GLWQA Annex(es): 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 9: Physical environment integrity

GLFC Objective(s):

Beneficial Use Impairment(s):

# Area, Quality, and Protection of Special Lakeshore Communities

## Indicator ID: 8129

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### **Measure**

Area, quality, and protected status of twelve special lakeshore communities occurring within 1 kilometre (km) of shoreline. 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.

### **Purpose**

To directly measure changes in area and quality of the twelve special lakeshore communities and to indirectly identify the sources of threats to some of the most ecologically significant habitats in the Great Lakes terrestrial nearshore, as well as to indirectly measure the success of management activities associated with the protection status.

### **Ecosystem Objective**

Relates to IJC Desired Outcome 6: Biological Community Integrity and Diversity.

### **Endpoint**

No net loss in area or quality of the twelve special lakeshore communities.

### **Features**

The twelve special lakeshore communities presented in this indicator are identified in "Land by the Lakes," a paper from SOLEC '96, as some of the most ecologically significant habitats in the terrestrial nearshore. This indicator will map the location and extent of these special lakeshore communities from existing studies (where available), Biological Conservation Databases, remote sensing and aerial photos, and land use planning data. The quality of special lakeshore communities will be ranked using criteria such as size, condition, and landscape context. In addition to location and quality, this indicator will identify the protection status related to each identified special lakeshore community (e.g., public conservation ownership, private conservation ownership, protective land use policies), as well as the severity of threats to the quality of each community, such as the presence of invasive exotic species.

### **Illustration**

Colour mapping could show the distribution of each special lakeshore community, ranked by quality or degree of protection for each lake, ecoregion, or the basin. Bar charts could highlight changes over time for each community, or compare the current area to estimates of the original area. A preliminary analysis of sand dune complexes across the Great Lakes basin by The Nature Conservancy's Great Lakes Program provides an example of how the results could be portrayed. In addition to charts showing the percentage of protective ownership, this model illustrates the severity of different types of stresses affecting this community.

### **Limitations**

Data collection may be difficult for many reasons. Collection of detailed data on a regular basis may be difficult due to the large area and the number of different jurisdictions to be examined. Identification of special lakeshore communities using aerial photography may prove easy for some communities and more difficult for others. Lastly, information on location and quality for some special lakeshore communities is incomplete, therefore, this indicator will require some expense to establish a reliable baseline.

### **Interpretation**

A baseline of the area of each of the twelve special lakeshore communities will be established for comparison with periodic monitoring every 3-5 years to identify changes. As more information becomes available, this indicator could provide a more detailed analysis of changes in area and habitat quality within each of the communities, as well as a better understanding of the threats to these communities. Quality rankings for each occurrence of a special lakeshore community can be based on techniques developed by state/provincial Heritage Programs, which establishes classes for size, assesses condition based on disturbance and the presence/absence of sensitive species, and rates the degree of connection and buffering provided by the surrounding landscape context.

### **Comments**

This indicator provides easily understood information on the ongoing loss of the best of Great Lakes shoreline communities. The information conveyed by this indicator will help to focus attention and management efforts on the special communities undergoing the greatest rate of change.

### **Unfinished Business**

### **Relevancies**

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): habitat

SOLEC Grouping(s): nearshore terrestrial

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13:  
Pollution from non-point sources

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

## Extent of Hardened Shoreline

### Indicator ID: 8131

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#### **Measure**

Kilometres of shoreline that have been hardened through construction of sheet piling, rip rap and other erosion control shore protection structures. (Does not include artificial coastal structures such as jetties, groynes, breakwalls, piers, etc.)

#### **Purpose**

To directly measure the amount of shoreline habitat altered by the construction of shore protection, and to indirectly measure the potential harm to aquatic life in the nearshore as a result of conditions (i.e., shoreline erosion) created by habitat alteration.

#### **Ecosystem Objective**

Shoreline conditions should be healthy to support aquatic and terrestrial plant and animal life, including the rarest species. Relates to the International Joint Commission (IJC) Desired Outcome 9: Physical Environment Integrity.

#### **Endpoint**

No net increase in the amount of hardened shoreline along any of the Great Lakes or connecting channels.

#### **Features**

There is limited historical data available on this indicator, but estimates of the extent of shore protection were made as part of an IJC reference in 1992. Data collection for this indicator could include estimates based on aerial photography and limited field studies, with a focus on Areas of Concern and sites identified from the 1992 IJC data where shoreline hardening appears to be increasing.

#### **Illustration**

A bar chart for each lake, or reaches within lakes, could document the annual change in the amount of hardened shoreline.

#### **Limitations**

The field data needed to assess the actual length of new hardened shoreline each year would be costly. A commitment to collect data within selected areas every 5 years might be more achievable.

#### **Interpretation**

The degree of negative impact to aquatic life in the nearshore will vary depending on the design of the protection and on the antecedent conditions. Some types of hardened shoreline induce more severe impacts than do others. A classification scheme that reflects the degree of impacts from different types of shore protection should be developed, based on a literature review.

#### **Comments**

Some types of shore protection create conditions that are not hospitable to aquatic life in the nearshore. This indicator will measure the extent to which this is occurring.

#### **Unfinished Business**

< Need to provide a baseline year and a baseline amount of hardened shoreline for the endpoint.

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): land

Related Issue(s): habitat

SOLEC Grouping(s): nearshore terrestrial, land use

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat



# Nearshore Land Use Intensity

## Indicator ID: 8132

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### **Measure**

Land use types, and associated area, within 1 kilometre (km) of shore. Land use types could include urban residential, commercial, and industrial, non-urban residential, intensive agriculture, extensive agricultural, abandoned agricultural, closed-canopy forest, harvested forest, wetland and other natural area.

### **Purpose**

To directly measure the types and extent of major land uses and to indirectly measure the effects of land use on significant natural features or processes, particularly on the twelve special lakeshore communities as defined in "Land by the Lakes," a paper from the SOLEC '96. 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.

### **Ecosystem Objective**

Healthy nearshore terrestrial ecological communities will be maintained. Relates to IJC Desired Outcomes 6: Biological Community Integrity and Diversity and 9: Physical Environment Integrity.

### **Endpoint**

No net loss or alteration of significant natural features or processes from current conditions.

### **Features**

This indicator will track trends in terrestrial nearshore land uses over time (ideally 5 to 10 year periods) and focus on identifying areas experiencing the greatest changes in land use intensity over time. To identify and map terrestrial nearshore land uses, this indicator will rely on a variety of methods, including remote sensing; aerial photography; available land use planning data for areas identified as already experiencing rapid land use changes (e.g., urban areas and cottage development); municipal data on building permits; and official plan/zoning bylaw amendments. Subsequent yearly monitoring will establish an increase or decrease in the extent of major land use types. This indicator is related to indicator #8136, Nearshore Natural Land Cover.

### **Illustration**

For each lake basin, lake, jurisdiction, and ecoregion, a table or graph will display annual changes in the area and degree of interspersions of each land use.

### **Limitations**

Data collection may be difficult for many reasons. Collection of detailed data on a regular basis may be difficult due to the large area and the number of different jurisdictions to be examined. Differences in types of land use planning data collected by jurisdictions may also hamper the collection of consistent data to support this indicator. Some limited historical data are available on land use types, but these data are focused on specific areas. A few basin-wide studies have been conducted that would provide a basic description of land use trends (e.g., U.S. National Shoreline Inventory from the early 1970s and a recent IJC water levels reference study) but it may be difficult to compare these data due to differences in methodology and generalizations that may have been used.

### **Interpretation**

Developing a baseline for this indicator will require both a review of existing data sources to determine their usability, and a discussion among agencies to establish a common list of land use types and parameters. Computerized analysis of satellite imagery may provide a cost-effective means of data collection for the overall nearshore area. A more detailed study and ground-truthing of selected areas, however, will be needed to assess the relationship of land use changes to the loss or alteration of significant natural features and processes. In particular, results from this indicator should be compared to results from indicator #8129, Area, Quality, and Protection of Special Lakeshore Communities, to assist in identifying land use change patterns that threaten natural habitats.

### **Comments**

### **Unfinished Business**

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): land

Related Issue(s): habitat

SOLEC Grouping(s): nearshore terrestrial, land use

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13:  
Pollution from non-point sources  
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity  
GLFC Objective(s):  
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

## Nearshore Plant and Wildlife Problem Species

### Indicator ID: 8134

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#### **Measure**

Type and abundance of plant and wildlife problem species, including white sweet clover, leafy spurge, spotted knapweed, garlic mustard, white-tailed deer, and Brown-headed Cowbird, within 1 kilometre (km) from shore.

#### **Purpose**

To directly measure the type and abundance of plant and wildlife problem species in landscapes bordering the Great Lakes and to indirectly measure the potential threat to the health of nearshore ecological processes and communities.

#### **Ecosystem Objective**

Healthy nearshore ecological processes and communities in the Great Lakes should be free of disruptive problem species. Healthy populations of grassland/forest interior bird species should be undisturbed by parasitic species. Preserve/restore larger intact ecosystems to support healthy nearshore ecological processes and communities in the Great Lakes. Relates to International Joint Commission (IJC) Desired Outcome 6: Biological Community Integrity and Diversity.

#### **Endpoint**

1) For problem plant species, the desired outcomes are a) eradication at key sites, defined as excellent examples of representative communities or globally rare communities, and b) a downward trend from current levels in the abundance of these species in other nearshore areas.

2) For deer, the desired outcomes are a) the successful regeneration of all native plant species that are browsed by deer, including white cedar, Canada yew, northern red oak, Trillium grandiflorum; b) intact vegetation structures (e.g., canopy, sub-canopy, shrub and forest floor layers) within areas browsed by deer; and c) the deer density is below a level defined regionally as a sustainable population.

3) For cowbirds, the desired outcome is a decrease in parasitism to levels that allow recruitment by host bird species (e.g., Wood or Swainson's Thrush, Veery, Red-eyed Vireo, Black-and-white Warbler, Ovenbird, Savannah Sparrow, Bobolink) to meet or exceed the replacement rate of at least 2.0 young fledged/nest/year.

#### **Features**

This indicator will track changes in presence and abundance of plant and wildlife problem species over time. Exotic plant species are indicative of disrupted ecological processes in ecological communities. They tend to displace native species and further disrupt the dynamics of plant communities. White sweet clover, leafy spurge and spotted knapweed are found in open habitats while garlic mustard occurs in forests. White-tailed deer and Brown-headed Cowbirds are indicative of landscape changes where there is much habitat fragmentation and a high proportion of early successional habitats. Population levels of problem species and forest or grassland interior bird species that serve as host to cowbirds should be monitored at selected sites along each of the Great Lakes in landscapes ranging from highly fragmented to unfragmented. Vegetation monitoring within wintering areas for deer should also be carried out. Special attention should be paid to those areas experiencing considerable change. For example, the indicator should communicate if the problem species are expanding or reducing their influence in areas at the edge of their range and/or in areas undergoing restoration. Monitoring at reference sites scattered along the shoreline will be critical.

#### **Illustration**

For each lake, this indicator will present changes in mean number/productivity per unit area per site for problem species or for forest and grassland interior bird species that serve as host to cowbirds. This indicator will divide sites into fragmented and unfragmented landscapes bordering each side of each Great Lake. The illustration for this indicator will display on a bar chart trends by year for each site representing a fragmented and unfragmented landscape. This indicator will also display the occurrence and recruitment for white cedar, northern red oak, Canada yew, Trillium grandiflorum, as well as the vegetation structure at these same sites to show the effects of problem species on natural communities.

#### **Limitations**

Distributions of native and alien species within 1 km of Great Lakes shorelines are generally known, although densities are poorly described. Densities of some species (deer, Swainson's Thrush, Red-eyed Vireo, Black-and-white Warbler) are known at only a few locales, or not at all. Data on presence/absence of problem species are relatively easy to collect but would require basin-wide coordination of botanists, deer biologists, and ornithologists to accomplish. Collection of data on the densities of problem species requires training, standardized data collection techniques, and accounting for observer bias. Data on the productivity of problem species are very costly to obtain, especially on a sustained basis. It would be best to collect these data at longer intervals.

#### **Interpretation**

A number of other factors will need to be considered in interpreting this indicator. Changes in abundance, density, and productivity of native nearshore ecological communities are caused by factors other than the degree of habitat fragmentation,

the amount of available habitat, and interactions with invasive exotic species. Factors such as connectivity and the survivorship of birds on migration routes and wintering areas will influence abundance density and productivity, and therefore, will affect the interpretation of this indicator. In general, increases in interior species and decreases in problem species, compared to a baseline of current populations, should be interpreted as good.

**Comments**

The list of problem species to be monitored for this indicator needs to be narrowed down. The number and location of monitoring sites for this indicator, as well as a definition of fragmented and unfragmented, need to be determined for this indicator. If the interface between aquatic and terrestrial ecosystems is addressed, purple loosestrife and Phragmites australis should be added to the list. Changes in responses (e.g., management efforts) to problem species should also be documented.

**Unfinished Business**

< Need to determine the level of parasitism by the cowbird that will allow recruitment of host bird species to meet or exceed the replacement rate of at least 2.0 young fledged/nest/year.

**Relevancies**

Indicator Type: pressure

Environmental Compartment(s): biota

Related Issue(s): exotics, habitat

SOLEC Grouping(s): nearshore terrestrial

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 17: Research and development

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

# Contaminants affecting Productivity of Bald Eagles

## Indicator ID: 8135

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### **Measure**

1) Concentrations of DDT Complex, PCB, PCDD, PCDF and other organic contaminants and mercury and other heavy metals in Bald Eagle eggs, blood, and feathers; 2) number of fledged young produced; and 3) number of developmental deformities.

### **Purpose**

To directly measure the concentrations of organic and heavy metal contamination in Bald Eagle eggs, blood, and feathers and to indirectly measure the concentrations, as well as identify the source, of these contaminants in the food web. Also, to directly measure injury to wildlife from organic and heavy metal contaminants, and an indirect measure of the potential harm to human health through the consumption of contaminated fish.

### **Ecosystem Objective**

Relates to IJC Desired Outcomes 6: Biological Community Integrity and Diversity and 7: Virtual Elimination of Inputs of Persistent Toxic Substances.

### **Endpoint**

1) Concentrations of organic and heavy metal contaminants less than the NOAEL in eggs, blood, and feathers; 2) productivity rate of 1.0 young per occupied breeding area annually; and 3) no observed developmental deformities in nestlings.

### **Features**

Annual productivity data exists for Bald Eagle breeding areas in the Great Lakes since early 1960s. Data exists on the concentrations of contaminants in eggs and feathers since late 1960s. Annual inspection of nestlings during banding provides rates of expressed deformities.

### **Illustration**

For each lake, and subunits within each lake, the following trends will be shown graphically: concentrations of organic and heavy metal contaminants; yearly productivity; and, areas where deformities have been documented. -Illustrations for this indicator will also present territories and habitat suitability indices. The data from 1970-1998 will be displayed; data prior to 1970 may have inconsistencies.

### **Limitations**

Eagles do not nest on every shoreline of every Great Lake. They are highly viewed by the public and not a good laboratory animal. They can be linked with the presence of colonial waterbirds and osprey using conversion factors to generate a better geographic representation.

### **Interpretation**

Biological endpoints specifically related to persistent toxic substances addressed by the GLWQA are well known and are published in the peer-reviewed literature on cause-effect linkages.

### **Comments**

This indicator is one of few that has been tested in the field. It is one of the best indicators identified by the IJC in relation to the GLWQA because long-term data are available and there are known reproductive effects.

Reproductive failure, depressed reproduction, increased incidence of teratogenic effects, and behavioral effects (related to food gathering or parenting skills) are used as endpoints and related various PTS concentrations. Since different PTSs have different effects, multiple endpoints are necessary. Also, since the effects change based on concentrations in the biological matrix measured (blood, egg, feather), multiple endpoints are necessary so that progress toward recovery from PTSs can be measured.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): biota

Related Issue(s): toxics

SOLEC Grouping(s): open waters, nearshore waters nearshore terrestrial

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 5: Bird or animal deformities or reproductive problems

# Extent and Quality of Nearshore Natural Land Cover

## Indicator ID: 8136

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### **Measure**

Percent of natural land cover types within 1 km of the shoreline that meet minimum standards of habitat quality.

### **Purpose**

To directly measure the amount of natural land cover that falls within 1 km of the shoreline and to indirectly measure the impact of artificial coastal structures and primary/secondary home development on the extent and quality of nearshore terrestrial ecosystems in the Great Lakes.

### **Ecosystem Objective**

Maintain the health and function of a representative number of shoreline natural land cover types. Relates to IJC Desired Outcome 6: Biological Community Integrity and Diversity.

### **Endpoint**

Shoreline natural land cover types will be 1) well represented, and 2) healthy. To determine if natural land cover within 1 km of the shoreline is well-represented and healthy, additional work is required to develop quantitative endpoints.

### **Features**

This indicator will track changes in the number of hectares of coastal communities on the Great Lakes over time. Natural land cover within 1 km of the shoreline generally includes areas that: provide important habitat to migrating birds; contribute sediment and chemical loadings to streams and the lake; preserve the integrity of river-mouth wetlands; and sustain other nearshore natural processes. Only cover type occurrences that meet minimum quality standards would be included. These standards could be based on occurrence size (e.g., over 2 acres), condition, and landscape context, using similar criteria to those in indicator #8129, Special Lakeshore Communities. It is not likely that the natural land cover within 1 km of the shoreline has been assessed in many areas around the Great Lakes. A baseline should be established (i.e. 2000) with re-mapping occurring every ten years (i.e., 2010, 2020) to track trends in land cover change. Data from this 1 km zone can be linked with land cover analysis occurring further inland to report on the health of entire watersheds. Data collection for this indicator should be done in conjunction with indicator #8132, Nearshore Land Use Intensity.

### **Illustration**

The percentage of land cover within 1 km of the shoreline can be mapped using remote sensing products, such as satellite imagery, and then displayed on geographic information systems (GIS). Different types of vegetation communities can be analyzed and displayed for a particular area of shoreline, or for the entire shoreline of a Great Lake using the GIS. The resulting information could be portrayed as bar charts for each area, showing both comparisons between cover types and changes over time.

### **Limitations**

Information on historical vegetation communities is likely available in surveyors records, early journals, and old air photos and will need to be assembled. Although this is a relatively inexpensive indicator, because much of the remote sensing mapping and GIS software is likely already available, there will be costs involved in adapting existing data to report on the 1km shoreline zone (i.e., joining maps, integrating data at different scales). Establishing a baseline should not be very costly. Costs will rise as this indicator is related to other information (see Interpretation field).

### **Interpretation**

This indicator will show whether the nearshore natural land cover is increasing or decreasing in comparison to the baseline, and what kinds of changes are taking place. The information contained in this indicator will be more useful if coupled with other indicators that measure changes in other components of the Great Lakes nearshore terrestrial ecosystems. For example, information on changes in the presence and abundance of birds, reptiles, amphibians, plants and other nearshore terrestrial species dependent on land cover within 1 km of the shoreline will provide a better understanding of how changes in the percentage of natural land cover affects the ecosystem.

### **Comments**

The information needed to develop endpoints for this indicator is likely available, but will require a literature search and discussions with additional experts. Representatives from the Long Point and Whitefish Point Bird Observatories should be consulted on the requirements of migratory birds in the shoreline zone. Assembling the historical and current vegetation community information for the 1 km shoreline zone should be undertaken in partnership with other SOLEC groups who are interested in adjacent watersheds because much of the baseline information will be common to both interests.

A more detailed definition of the types of natural land cover to be included in this indicator needs to be developed. Data collection efforts should use satellite imagery at the best resolution available (i.e., 5 or 20 metres) and refine information for specific areas of interest along the lakes using aerial photography.

## ***Unfinished Business***

### ***Relevancies***

Indicator Type: state

Environmental Compartment(s): land

Related Issue(s): habitat

SOLEC Grouping(s): nearshore terrestrial

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environment integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

# Nearshore Species Diversity and Stability

## Indicator ID: 8137

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### **Measure**

The type and number of plant and wildlife species, and vegetation regeneration rates within the nearshore area, defined as the area within 1 kilometer (km) of the shoreline.

### **Purpose**

To directly measure the composition and abundance of plant and wildlife species over time within the nearshore area and to indirectly measure of adverse effects on the nearshore terrestrial ecosystem due to stresses such as climate change and/or increasing land use intensity.

### **Ecosystem Objective**

Relates to the IJC Desired Outcomes 6: Biological Community Integrity and Diversity, and 7: Virtual Elimination of Inputs of Persistent Toxic Substances.

### **Endpoint**

Naturally-regenerating nearshore plant and wildlife communities with a diversity of native species equivalent to historical populations.

### **Features**

This indicator will track changes in nearshore plant and wildlife species composition and abundance over time. Plant and wildlife species in the nearshore area are sensitive to changes in environmental and habitat conditions. This indicator could draw on several existing sources of information, as well as encourage new data collection. Ontario, Canada, and most States have comprehensive data sets for breeding birds on a geo-referenced 10 km x 10 km grid that is periodically updated. Similar data are available for herptiles, mammals, and trees, although they are less likely to be comprehensive. For some sites along the shoreline, historical data are available on the regeneration of species such as White Cedar, White Pine, and Canada Yew. Changes in regeneration rates of these species, or of other communities such as lichens, are indicative of either local pressures such as deer browsing, or broader-scale environmental changes, such as air pollution. As new data becomes available (on a 10-15 year cycle for comprehensive coverage), changes over time can be observed.

### **Illustration**

Using existing breeding bird data, a map could be readily generated showing shoreline cells (i.e. the number of species within their normal breeding range) with the number of breeding species within each as a percentage of the total number of species within their breeding range.

### **Limitations**

Comprehensive data is not available for all species groups, and data collection is laborious and largely volunteer-based. Even for the best data sets, such as the data set on breeding birds, coverage is incomplete in more remote areas. Historical data on regeneration rates is highly site-specific, and available for relatively few sites.

### **Interpretation**

These data can be compared to the total number of species that could be expected within each shoreline cell. For some species, population ratios could also be derived as well, as a comparative measure of stress - for example, classing the population of a species within each cell as abundant, common, scarce, or rare. The nature of observed changes over time can indicate different kinds of stresses. For example, a uniform decrease in the diversity of breeding species could indicate a broad-scale stress such as climate change; decreases only on urban fringes while more remote areas stay the same would more likely point to local habitat changes. It would be useful to divide the data between resident and long distance migrant birds in order to separate local from broad impacts.

### **Comments**

As part of the indicator development, priority species, which could be groups of birds, woodland frogs, etc., should be selected.

In regional studies carried out in southern Ontario by the Federation of Ontario Naturalists, this method showed a range in values from 100% of expected species in good habitats to less than 70% in areas with degraded conditions.

### **Unfinished Business**

< Need to develop a more quantitative endpoint.

### **Relevancies**

Indicator Type: state

Environmental Compartment(s): biota



Related Issue(s): exotics, habitat

SOLEC Grouping(s): nearshore terrestrial

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

## Community/Species Plans

### Indicator ID: 8139

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#### **Measure**

Number of plans that are needed, developed, and implemented to maintain or restore high quality, natural nearshore communities — those within 1 kilometre (km) of the shoreline — and federally/nationally listed endangered, threatened, and vulnerable species.

#### **Purpose**

To directly measure the number of plans that are needed, developed, and implemented to maintain or restore high quality, natural nearshore communities and federally/nationally listed endangered, threatened, and vulnerable species, and to directly measure the type and number of communities and species that require protection. This indicator will also indirectly measure the type and number of communities that will potentially be maintained/recovered through plan development and implementation.

#### **Ecosystem Objective**

Programs should be responsive to the degradation of shoreline communities and species. Relates to IJC Desired Outcome 6: Biological Community Integrity and Diversity.

#### **Endpoint**

Implementation of plans that contained recommended action steps and associated timetables to maintain/recover all significant nearshore natural communities and endangered/threatened/vulnerable species populations identified to date within the nearshore area.

#### **Features**

This indicator will compare the number of plans that are needed, developed, and implemented over time. Plans are needed for any species or community that is officially designated as endangered, threatened, or vulnerable (rare) at the federal/national level. The plans will describe the existing community/species status by addressing natural quality, threats, signs of disturbance; natural diversity; rare species (communities) and population size; reproductive success, threats, and recovery needs (species); and recommended action steps. Well-crafted plans will enable monitoring and appropriate conservation measures over time. Implementation of these plans is defined as tangible, on-the-ground management activities that can be shown to be making a measurable difference in the community/species status.

#### **Illustration**

To illustrate this indicator, a bar chart will be presented that summarizes the number of plans needed, developed, and implemented for each lake, and tracks progress over time.

#### **Limitations**

Tracking the communities/species needing plans and with plans developed should be relatively easy, in conjunction with the federal/national agencies with responsibilities for endangered species. Collecting and analyzing data on implementation in a consistent way may be more difficult.

#### **Interpretation**

This indicator should provide a relatively straightforward measure of the attention devoted to communities/species at risk. However, the actual success of these measures will depend largely on the adequacy of the plans and their implementation. Research should be encouraged to address the relationship between the number of plans implemented and the actual maintenance/recovery of natural communities and endangered/threatened/vulnerable species populations.

#### **Comments**

##### **Unfinished Business**

< Need to determine a reference value that will be used to quantify this endpoint. For example, the endpoint for this indicator might be the implementation of a certain percentage of plans from a total number identified as needed during a baseline year. Or the reference value could be implementation of all plans developed during the previous year.

#### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): biota

Related Issue(s): stewardship

SOLEC Grouping(s): nearshore terrestrial, societal

GLWQA Annex(es): 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s):

# Shoreline Managed Under Integrated Management Plans

## Indicator ID: 8141

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### **Measure**

Percent of shoreline managed under an integrated shoreline management plan. An integrated shoreline management plan is one that includes consideration of coastal processes, aquatic habitat, and designates appropriate setbacks, etc. and is incorporated into local planning documents (e.g. a municipal Official Plan).

### **Purpose**

To directly measure the amount of Great Lakes shoreline managed under an integrated management plan, and to indirectly measure the degree of stewardship of shoreline processes and habitat.

### **Ecosystem Objective**

Programs should be responsive to the degradation of shoreline communities and species. Relates to IJC Desired Outcomes 6: Biological Community Integrity and Diversity, and 9: Physical Environment Integrity.

### **Endpoint**

The target is 100% of shoreline under "good" pro-active management.

### **Features**

This indicator will track trends in integrated shoreline management plans over time. It will point to areas of the Great Lakes shoreline that are subject to poor or no coastal management. These trends can be used to direct future shoreline management activities.

### **Illustration**

For each of the lakes, this indicator will display a map of shorelines and highlight segments under poor, moderate and good management. This indicator could also be displayed using a pie chart that illustrates the percent of shoreline under the three types of management.

### **Limitations**

Information on quality of shoreline management plans has not been measured across the Great Lakes basin. Existence of shoreline management plans indicates an intent to manage the shoreline accordingly, but does not demonstrate actual compliance or implementation. However, an integrative plan, one that is adopted/incorporated into land use planning documents, does demonstrate serious intent. It is difficult to determine compliance with the plan, or calculate how many zoning variances or amendments have been granted, and it would be too much effort to measure. By focusing on integrated plans, this indicator addresses only part of shoreline planning efforts. Other management plans and programs, including efforts of local municipalities, non-government agencies and the private sector could be considered as these are becoming increasingly important and will continue into the future.

### **Interpretation**

To determine the percentage of shoreline under "good" pro-active management, this indicator could use the following 3- tiered ranking: "poor" = no plan at all; "moderate" = an old plan or a new one that has not actually been adopted; and "good" = an integrated plan that has been incorporated into land use documents. This information could be collected through a survey of shoreline management agencies. Results should be easy to present in an understandable format.

### **Comments**

Some initial research on the potential for integrated shoreline management planning by province and states has been done by Patrick Lawrence at University of Waterloo, along with a focus on continued research on the capacity of Ontario municipalities to undertake Great Lakes shoreline management.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): land, humans

Related Issue(s): stewardship

SOLEC Grouping(s): nearshore terrestrial, land use, societal

GLWQA Annex(es):

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s):

## Artificial Coastal Structures

### Indicator ID: 8146

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#### **Measure**

The number and type of artificial coastal structures (including groynes, breakwalls, riprap, piers, etc) on the Great Lakes shoreline. Artificial coastal structures include structures that extend into shallow waters at an angle from the shoreline, or are placed offshore for the purpose of breaking the force of the waves. They are distinct from the hardened shoreline works described in indicator #8131, Hardened Shoreline, which modify the shoreline edge itself.

#### **Purpose**

To directly measure the number of artificial coastal structures on the Great Lakes and to indirectly measure potential harm to coastal habitat by sand transport disruption.

#### **Ecosystem Objective**

Limit impact to natural features and processes in the terrestrial nearshore and nearshore waters environments. Relates to IJC Desired Outcome 9: Physical Environment Integrity.

#### **Endpoint**

Modification or removal of artificial coastal structures which are shown to negatively affect coastal sand transport, and restoration of natural coastal transport and deposition processes.

#### **Features**

This indicator will present trends in the number of coastal structures over time. From aerial photos and existing data sets, a baseline of artificial shoreline structures will be established. Yearly monitoring will be performed to determine if there is an increase or decrease in the structures. An increase will signify potential increased coastal sand transport disruption.

#### **Illustration**

A graph with the number of artificial structures on the y axis and the year on the x axis.

#### **Limitations**

It may be difficult to monitor the number of structures on a yearly basis and correlate with the degree of disruption of sand transport in specific sites. Monitoring could be done every 3-5 years, or in periods directly following high lake levels, when many of these structures tend to be built.

#### **Interpretation**

An increase in the number of artificial shoreline structures in comparison to the baseline will signal a disruption of the coastal process of sand transport.

#### **Comments**

Refer to IJC water level reference study for a classification of shore protection types and summaries of the % length by lake and shoreline reach.

#### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): land

Related Issue(s): land use

SOLEC Grouping(s): nearshore terrestrial

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

# Contaminants affecting the American Otter

## Indicator ID: 8147

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### **Measure**

1) Concentrations of heavy metals (e.g., Hg, Pb, Cd) found in hair, blood, liver, and brain of the American otter; and 2) concentrations of DDT and metabolites, PCBs/ PCDFs/PCDDs, Dioxin, and other organic contaminants found in fatty tissues, liver, and blood of the American otter.

### **Purpose**

To directly measure the contaminant concentrations found in American otter populations within the Great Lakes basin and to indirectly measure the health of Great Lakes habitat, progress in Great Lakes ecosystem management, and/or concentrations of contaminants present in the Great Lakes.

### **Ecosystem Objective**

Relates to IJC Desired Outcomes 6: Biological Community Integrity and Diversity, and 7: Virtual Elimination of Inputs of Persistent Toxic Substances.

### **Endpoint**

1) Maintenance of otter populations in the upper lakes, and restoration of sustainable otter populations to lower Lake Michigan, Lake Ontario and Lake Erie watersheds and shorelines; 2) Great Lakes shoreline and watershed populations of American otter should have an annual mean production > 2 young/adult female; and 3) concentrations of heavy metal and organic contaminants should be less than the NOAEL found in tissue samples from mink as compared to otter tissue samples.

### **Features**

American otters are a direct link to organic and heavy metal concentrations in the food chain. The species has primarily a piscivorous diet, but feeds on a wide array of other aquatic organisms. It is also more sedentary than avian species associated with aquatic food chains and subsequently synthesizes contaminants from a smaller area. It has an appropriate application to measure environmental contaminants on a Great Lakes level, but also on a localized scale. Changes in the species population and range are also representative of anthropogenic riverine and lacustrine habitat alterations. Indications of contaminant problems have been noted by decreased population levels, morphological measures (i.e. baculum length) through necropsies and declines in fecundity. Most State resource management agencies perform necropsies to determine an index of fecundity, deformities, growth rates, age and general health of a given population. Fecundity data from necropsies should be expressed by county and provincial management district annually. Limited toxicological studies have been conducted on Great Lakes otter. Trapping data has been intermittently available since 1835 in the Great Lakes region as an index of species abundance. In Ontario and the Great Lake States, except Ohio, trapping success has been used to model populations.

### **Illustration**

Annual trapping success expressed by total killed and number of otter killed/trapper by county and provincial management district adjacent to Great Lake shorelines from 1950 to the present. Contaminant concentrations and trapping success data could be presented as bar charts showing trends over time, or on a map of the Great Lakes basin showing comparative data among management districts.

### **Limitations**

American otters are difficult to maintain for controlled experiments and are highly visible to the public. There is very little toxicological data available on the species for the Great Lakes. Otters have limited populations in the lower Great Lakes. The method of modeling otter populations by harvest success and using indices of fecundity does not accurately measure population levels in the Great Lakes. Little published data exists on the ecology of otters in the Great Lakes region.

### **Interpretation**

Interpretation of this indicator may prove difficult since the ecology of the species and toxicological profiles from the region remain essentially unknown. No data are available on cause and effect linkages for otter in the Great Lakes. Otter are usually compared to contaminant levels in mink because the end points of a toxicological effect are better understood.

### **Comments**

The potential of the American otter as a Great Lakes Indicator makes intuitive sense. However, more information on its ecology and cause and effect linkages to contaminant problems in the Great Lakes region need to be determined to increase the utility of this indicator.

Resource management agencies should be encouraged to search for and monitor otter toilets on or near Great Lake shorelines for activity annually to note changes in distribution and stability in populations in relationship to sub-units of the Great Lakes that are known to be contaminated.

This proposed indicator was the most contentious of the nearshore terrestrial set, with some commenters suggesting that it be dropped, or replaced with monitoring of otter reproduction. In their view, otter reproduction would provide a measure that is more useful in assessing progress toward the GLWQA objectives versus evidence of reductions inferred from chemical analyses and conservative benchmarks. There is also concern that otter contaminant monitoring duplicates the mink indicator.

In response, other reviewers noted that mink are less common than otters in Lake Superior island environments (where they could provide an indicator that would not be influenced by mainland anthropogenic influences), and that mink are extremely problematic to study in the field. Otter differ entirely from mink in their habits and habitats. Otter are far more easy to trap safely and study in the field, and transmitter durations of 3-5 years are possible. They are observable during the day, and their sign is more obvious than that of mink. The territorial behavior of the American otter facilitates the determination of population densities and assists in monitoring efforts. They also live longer than mink, therefore, they synthesize environmental influences for a longer period. Study skins and furs up to 150 years old are available, allowing a historical analysis of metal concentrations in hair. This historical information could not be collected using mink. Literature worldwide documents anthropogenic toxins as one reason for otter populations declining in many parts of the world.

### ***Unfinished Business***

#### ***Relevancies***

Indicator Type: pressure

Environmental Compartment(s): biota

Related Issue(s): toxics

SOLEC Grouping(s): coastal wetlands, nearshore terrestrial

GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 5: Bird or animal deformities or reproductive problems

## Protected Nearshore Areas

### Indicator ID: 8149

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#### **Measure**

The percentage of the Great Lakes shoreline under various levels of protection in six classes as defined by the International Union for the Conservation of Nature (IUCN). The six IUCN classes are 1) strict protection, such as nature reserves and wilderness; 2) ecosystem conservation and recreation, such as national parks; 3) conservation of natural features, such as natural monuments; 4) conservation through active management, such as wildlife management areas; 5) protected landscapes/seascapes; and 6) managed resource protected areas, such as sustainable use areas.

IUCN. 1994. Guidelines for Protected Areas Management Categories. Commission on National Parks and Protected Areas with the assistance of World Conservation Monitoring Centre. Gland, Switzerland, and Cambridge, U.K.

#### **Purpose**

To directly measure the kilometers/miles of shoreline in protective status and the kind of protection in place and to indirectly measure 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 links in the migration (lifecycle) of birds and butterflies which migrate continentally.

#### **Ecosystem Objective**

The Great Lakes shall be free of... net loss of fish and wildlife habitat (GLWQA, Annex 2, item xiv). Relates to IJC Desired Outcome 6: Biological Community Integrity and Diversity. Also relates to several of Lake Superior LaMP's Habitat Objectives including: land and water uses should be designed and located in harmony with the protective and productive ecosystem functions; degraded features should be rehabilitated or restored; and, land use planning and regulation should eliminate or avoid destructive land-water linkages, and foster healthy land-water linkage.

#### **Endpoint**

Significant increase in extent of Great Lakes shoreline within formal protected areas.

#### **Features**

The reference values are the kilometers/miles of shoreline which are protected as a percent of the total shoreline and the percent of increase or decrease over time as measured every two to four years.

#### **Illustration**

For each selected area (e.g., basin-wide, lake, special shoreline community, ecoregion, etc.) graphs will be displayed with the percentage of protected area on the y axis and years on the x axis. Additionally, for each selected area, maps will be displayed that show the protected shoreline and its class of protection.

#### **Limitations**

Data on national parks and RAMSAR sites should be relatively easy to obtain. However, data from other locations require the cooperation of state/provincial and local authorities, who may not always have the resources to collect or maintain this information. If baseline data is not readily available, collecting the data will be resource-intensive, and therefore expensive. Subsequent data updates will require only moderate expense. This indicator is useless unless the data inventory is kept up to date and there is consistency in data treatment (database management and GIS) which will require readily available expertise, a continuing, low-level, effort in data management, and a consistent approach.

#### **Interpretation**

Once the baseline is established, the percent of the shoreline in protected status can be tracked. "Bad" or "good" trends will be determined by how the percent of the shoreline in protected status is changing over time. An increase in the percent of shoreline in protected status would be considered "good;" a decrease would be considered "bad." The indicator may be complemented by information on the status (ecological integrity, quality) of wetlands, natural land cover along the shoreline, and information on special communities. It may be interesting to show where protected areas and AOC/RAP or Biodiversity Investment Areas coincide, and where the information for this indicator is useful for the evaluation of RAPs or Biodiversity Investment Areas.

#### **Comments**

A protected area database has been kept at Environment Canada; whether it is up-to-date or not is unknown. Precise spatial information (precise location and extent, which part of the shoreline, how far inshore) is either not available or poor. In Canada, data for RAMSAR sites, national parks, or MAB sites should be easy to locate. It is not known how often this data is updated, or whether the sites are periodically monitored for their quality (ecological integrity). In the U.S., data on protected areas would have to be compiled from federal and state agency sources. A useful starting point for relevant data can be found in the Environmental Sensitivity Atlases for each of the lakes and connecting channels.

This indicator overlaps with coastal wetland indicators. It would be good to link the information with an indicator on the location, extent and quality of wetlands; also, to what extent these wetlands are protected. The indicator may need some refinement to express "representativeness" (proportion of special lakeshore habitat types included) or better links to "Important Bird Areas", or conservation plans.

- MAB Man and the Biosphere. Initiated by UNESCO to address problems relating to conservation of resources, resources systems, and human settlement development.
- RAMSAR The Convention on Wetlands, signed in Ramsar, Iran in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.
- UNESCO United Nations Educational, Scientific and Cultural Organization

### ***Unfinished Business***

#### ***Relevancies***

Indicator Type: human activity

Environmental Compartment(s): land

Related Issue(s): habitat

SOLEC Grouping(s): nearshore terrestrial

GLWQA Annex(es):

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s):



## Urban Density

### Indicator ID: 7000

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#### **Measure**

Human population per square kilometer of existing and proposed development areas. Total area is adjusted to exclude parks and other designated greenspace.

#### **Purpose**

To directly measure human population density and to indirectly measure the degree of inefficient land use and urban sprawl for communities in the Great Lakes ecosystem.

#### **Ecosystem Objective**

Socio-economic viability and sustainable development are generally accepted goals for society. In addition, this indicator supports Annex 13 of the GLWQA.

#### **Endpoint**

There is no conceivable upper end to urban densities from an ecosystem perspective since higher densities are associated with improved urban efficiency and reduced stress on the rest of the ecosystem. Thus higher densities are better.

#### **Features**

Urban density is a relative measure of efficiency. In general, and other things being equal, higher density land use is less energy and resource consuming and thus is more efficient from an ecosystem perspective. For example, transportation in higher density areas is less resource demanding since distances are shorter and public transportation is often more available and inexpensive. Consequently, air pollution should be lower in more densely populated areas. In addition, since inefficient land use for urban development implies loss of land use for natural and other purposes there are significant biodiversity dimensions to inefficient land use. In general, the less land used for development, the greater the opportunities that exist for natural biodiversity goals to be met. Urban densities have been declining over time as urban development has become much more sprawling with the vast majority of new development occurring on former agricultural or natural lands. This has resulted in greater reliance for urban residents on the automobile as virtually the only method of public transit for these widespread and low density new communities has become impractical. Information for this indicator needs to be collected perhaps every 5 or 10 years as changes in density take place relatively slowly.

#### **Illustration**

This indicator will be displayed by a numerical ratio of population to land area (population per square kilometer)

#### **Limitations**

This indicator is useful in comparing municipalities to each other, but would need to be aggregated into an index in order to be represented as a basin wide measure. Identifying park space may be complicated and difficult in some cases because the information most likely exists only at the local level and would require a survey to collect.

#### **Interpretation**

The indicator is a simple representation of urban efficiency since higher density communities typically are lower in cost and less intrusive on the rest of the ecosystem. Thus, the higher the ratio of population per square kilometer of land the better in achieving overall urban efficiency and a less stressed ecosystem.

#### **Comments**

The indicator is also a good proxy for commercial and industrial sprawl since development patterns for this sector typically parallels that of residential development. The socio-economic paper of SOLEC '94 indicated the relative urban densities between the City of Toronto, Ontario and Chicago, Illinois. The SOLEC '96 Land Use paper also discussed at length the efficiency aspects of higher density through the report.

#### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): land

Related Issue(s):

SOLEC Grouping(s): land use

GLWQA Annex(es): 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s):

## Land Conversion

### Indicator ID: 7002

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#### **Measure**

Percent change in land use type, including agriculture, urban development, and forest, marsh or other natural cover.

#### **Purpose**

To directly measure changes in land use within the Great Lakes basin and to indirectly measure the potential impact of land conversion on Great Lakes ecosystem health.

#### **Ecosystem Objective**

Sustainable development is a generally accepted land use goal for Canadians and Americans. This indicator supports Annex 1, 3 and 13 of the GLWQA.

#### **Endpoint**

Zero change would be sustainable but probably unrealistic, while reversion of other uses to the natural ecosystem would be desirable.

#### **Features**

High rates of land conversion place stress on the natural ecosystem and are typically associated with inefficient land use, such as urban sprawl. Population growth is a driver for more development which displaces both agricultural and natural lands. Other things being constant, high conversion rates are associated with rapid rates of urban sprawl which is economically inefficient and displaces natural land that serves other biological purposes in the ecosystem or agriculture which in turn may convert land from natural uses. The conventional pattern of land conversion has been for urban growth to displace agricultural lands which, in turn, expand into remaining lands. Urban development also expands into natural lands.

#### **Illustration**

The indicator allows easy and visual interpretation of land use changes and trends. Land conversion is an evolutionary process and this indicator will be displayed as a graphical representation of land use by category in the basin.

#### **Limitations**

This indicator provides a measurement of the conversion of the land use type, but not of the change in quality of the land use. For example, conversion of a highly intensive, chemical-intensive agriculture area to an urban area, particularly one that is well-planned and utilizes environmental and resource conservation management plans, may result in less stress to the ecosystem. Also, urban development on excavated, landfill or other contaminated sites may also be positive changes.

#### **Interpretation**

Generally, land that converts from natural to agricultural and from natural and agricultural uses to developed uses is undesirable. Conversion back to natural uses would be desirable.

#### **Comments**

SOLEC '96 represented the rate of land converted from agriculture to developed urban uses. Clearly, loss of agricultural land in the basin places pressure on other lands such as forests and wetlands to be placed into agricultural uses. Satellite imagery might be useful in detailing the changes over time of the urban frontier actually developed and this indicator.

#### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): land

Related Issue(s):

SOLEC Grouping(s): land use

GLWQA Annex(es): 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s):

# Brownfield Redevelopment

## Indicator ID: 7006

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### **Measure**

Total acreage of redeveloped brownfields.

### **Purpose**

To directly measure the acreage of redeveloped brownfields and to indirectly measure the rate at which society responds to the opportunity to rehabilitate and reuse former developed land sites that have been degraded by poor use.

### **Ecosystem Objective**

Sustainable development is a generally accepted goal for North American society. In addition, this indicator supports Annex 1, 2, 3, and 13 of the GLWQA.

### **Endpoint**

Elimination of all brownfield sites.

### **Features**

The indicator would describe trends in brownfields redevelopment and urban renewal, including areas that technically can not be described as brownfields. The indicator is a measure of the rate at which society is employing former contaminated (typically industrial) sites to new and more environmentally compatible uses. Brownfields reuse offers an opportunity to reduce pressure on the ecosystem by slowing the rate of land conversion and typically increasing urban densities. Brownfields have been a result of historically poor industrial land use practices, particularly on the more heavily and early developed sites on the U.S. side of the basin. As time progresses pollution prevention has been utilized to reduce the likelihood of even more brownfields into the future. An inventory of contaminated sites is maintained by most provincial and state and federal governments, although a broader definition would require municipal involvement. The goal is to redeploy all of these lands as soon as possible.

### **Illustration**

The total number of identified acres of outstanding brownfield sites throughout the basin by state/province and lake basin. Bar graphs could be used to demonstrate changes over time.

### **Limitations**

The identification of brownfield sites is limited by the availability of information on vacant and redeveloped sites. Data for this indicator may not reveal an accurate trend in brownfield redevelopment, particularly if redevelopment on brownfield sites results in another use that causes further land contamination.

### **Interpretation**

Reducing the number of acres/square kilometers of brownfield sites can be seen as a positive development in the basin. Increasing brownfield inventories not only indicate challenges of dealing with contaminated sites but also opportunities for redevelopment.

### **Comments**

Numerous examples are available including one site in Detroit that has been converted to a public park. Others are typically reduced as urban housing or clean industrial use.

The achievement of the end point will depend on the opportunities available for new land uses as an alternative to land conversion.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): land

Related Issue(s):

SOLEC Grouping(s): land use

GLWQA Annex(es):

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s):

# Mass Transportation

## Indicator ID: 7012

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### **Measure**

Percent of commuters using public transportation.

### **Purpose**

To directly measure the percentage of commuters using public transportation and to indirectly measure 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.

### **Ecosystem Objective**

Sustainable development as interpreted by Canada and the U.S. through ongoing efforts of agencies, such as the Canadian National Roundtable on Environment and Economy, and more specifically pollution related as recognized in Annex 1, 3 and 15 of the GLWQA.

### **Endpoint**

A ratio over 50% would be desirable.

### **Features**

The indicator is a simple measure of the average number of commuters using public (mass) transit in urban centres throughout the basin. It is valuable in recognizing the socio-economic costs associated with urban form that contributes to highly energy intensive, highly polluting, non-productive and time wasting urban commuting. The indicator could be aggregated and used as a basin wide indicator. Data are typically collected by survey and may vary from community to community and with respect to periodicity.

### **Illustration**

The indicator is represented graphically by a ratio of daily working commuters that use public transit options including rail and road mass transit options.

### **Limitations**

The indicator is a proxy for efficiency of an urban community. It focuses only on work commuters as data is not available for other commuting purposes, such as recreation. Finally, not all public transit may be more efficient than the use of private automobiles, for example, empty buses running on low density suburban streets.

### **Interpretation**

Use of public transit for commuting in urban communities is typically more efficient than the private automobile. Less energy is required, less pollution created, more land can be dedicated to living/working space and less to unproductive roads and parking lots, less working and non-working time is wasted behind the wheel of a car, and the costs to the community are reduced by higher levels of urban transit use.

### **Comments**

Reducing the amount of time and the cost of travelling for work and pleasure will impact on total resource use in society as well as reducing the amount of unproductive time spent commuting to work and increasing recreational time. Greater adoption of mass transportation involves changes in urban development patterns as well as lifestyle.

The former City of Toronto, with a relatively dense and compact urban form had a relatively high level of mass transportation. That level fell considerably when the City expanded its municipal boundaries to include more suburban areas.

It is only a proxy measure of the efficiency of goods transportation.

### **Unfinished Business**

- < Need to determine the time-scale of indicator. For example, will the measurements provided for this indicator be taken on an annual basis? A biennial basis?...
- < Need to determine how the indicator will be presented? For example, this indicator could show trends in use of mass transit over time using a bar graph with percentage of commuters using public transportation on the y axis and years on the x axis.
- < Need to add a discussion related to understanding the trends presented by the indicator. For example, what baseline will be used to determine if 50 percent of commuters are using public transportation?

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): land

Related Issue(s):  
SOLEC Grouping(s): land use  
GLWQA Annex(es):  
IJC Desired Outcome(s):  
GLFC Objective(s):  
Beneficial Use Impairment(s):

# Sustainable Agricultural Practices

## Indicator ID: 7028

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### **Measure**

Number of Environmental and Conservation farm plans in place.

### **Purpose**

To directly measure the number of Environmental and Conservation farm plans and indirectly measure environmentally friendly practices in place; such as, integrated pest management to reduce the unnecessary use of pesticides, zero tillage and other soil preservation practices and measures to reduce energy consumption, and prevention of ground and surface water contamination.

### **Ecosystem Objective**

This indicator directly supports Annex 3 of the GLWQA.

### **Endpoint**

Sustainable agriculture through non-polluting, energy efficient technology and best management practices for efficient and high quality food production.

### **Features**

Given the key role of agriculture in the Great Lakes ecosystem, it is important to track changes in agricultural practices that can lead to better ecological integrity in the basin. The indicator identifies the degree to which agriculture is becoming more sustainable and has less potential to adversely impact the Great Lakes ecosystem. Integrated pest management and zero till soil management are typically part of an environmental farm management plan. It is expected that more farmers will embrace environmental planning over time.

### **Illustration**

The total number of farm environmental plans (or ecological plans) that are in place as a percentage of the total number of farms in the basin.

### **Limitations**

Plans vary from jurisdiction to jurisdiction and thus may lack consistency in terms of completeness of agricultural sustainable practices. In addition there is no standard way of knowing the state of implementation of these plans.

### **Interpretation**

Having an environmental management plan in place provides an incentive for farmers to commit to environmentally sound land use practices. The more plans in place the better. In future there may be a way to grade plans by impacts on the ecosystem. The first year in which this information is collected will serve as the base line year.

### **Comments**

### **Unfinished Business**

### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): land

Related Issue(s):

SOLEC Grouping(s): land use

GLWQA Annex(es): 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s):

## Green Planning Process

### Indicator ID: 7053

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#### **Measure**

Number of municipalities with environmental and resource conservation management plans.

#### **Purpose**

To directly measure the number of municipalities with environmental and resource conservation management plans in place and to indirectly measure the extent to which municipalities utilize environmental standards to guide their management decisions with respect to land planning, resource conservation and natural area preservation.

#### **Ecosystem Objective**

Sustainable development is a goal of North American society. This indicator supports Annex 3 and 13 of the GLWQA.

#### **Endpoint**

All municipalities should have an environmental and resource conservation plan.

#### **Features**

The indicator is an acknowledgment that municipalities with environmental and resource conservation management plans require resource conservation as a mandatory part of the municipal land use decision process. Ideally all municipalities in the basin will focus on limiting urban sprawl; incorporating a preference for high density, redevelopment and brownfield utilization; conserving of natural features and resources, such as natural watercourse retention and woodlot preservation; and promoting mass transit. Once a development plan (i.e., a plan submitted by developers for new development) has been approved, it is safe to assume that it has taken account of environmental considerations.

#### **Illustration**

The indicator will be a numerical ratio of municipalities that do have plans out of the total number of municipalities in the basin. This could be presented by maps or through simple numerical ratios.

#### **Limitations**

This indicator will provide a measurement of the number of green plans in place, but will not assess the quality of the plans or if they are being implemented.

#### **Interpretation**

An increasing number of plans over time represent a positive trend. The indicator will be used to determine improvements over time as more municipalities undertake to develop and implement these plans. Data collected during the first year will serve as a baseline.

#### **Comments**

Oakland County Michigan has a detailed provision that all developers must follow in order to develop their lands.

#### **Unfinished Business**

#### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): land, humans

Related Issue(s):

SOLEC Grouping(s): land use

GLWQA Annex(es):

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s):

## Water Use

### Indicator ID: 7056

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#### **Measure**

Water use per capita in the Great Lakes basin.

#### **Purpose**

To directly measure the amount of water used in the Great Lakes basin and to indirectly measure the amount of wastewater generated and the demand for resources to pump and treat water.

#### **Ecosystem Objective**

Sustainable development is societal goal for the Great Lakes basin. This indicator supports Annex 8 of the GLWQA.

#### **Endpoint**

Resource conservation means reducing the amount of water that is used and the amount of wastewater that results from that water use. Current North American water use rates are in excess of 300 litres per day - reducing that by 50% is desirable and consistent with some European countries.

#### **Features**

The indicator provides a quantitative measure of the rate at which natural resources are being used. For example, high levels of water use results in considerable wastewater pollution, that results in degraded water quality, as well as increased demand for energy to pump and treat water. The indicator is a gross measure of water supplied through water supply facilities in a jurisdiction divided by the total number of people in the jurisdiction.

#### **Illustration**

The indicator will be displayed as the water use per capita in liters/capita within jurisdictions in the basin and the basin as a whole.

#### **Limitations**

Data are readily abundant although it needs to be gathered in a consistent format. Ground water sources from private wells are excluded.

#### **Interpretation**

Water use symbolizes societal regard to resource use. North Americans, including those in the Great Lakes region, have very high rates of per capita water use compared with other developed nations, and reductions would result in reduced stress on the ecosystem. Water use is high and growing in places such as Toronto, in spite of efforts over the years to encourage water efficiency and conservation.

#### **Comments**

Canada and the United States are among the highest water using nations, per capita on the Earth.

#### **Unfinished Business**

< Need to add a discussion related to understanding the trends presented by the indicator. For example, will a baseline of "ideal" or "sustainable" water consumption rates need to be developed to determine if data collected on an annual basis (or another regular interval) reveals positive or negative trends in the amount of water consumed.

#### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): humans

Related Issue(s): stewardship

SOLEC Grouping(s): land use, societal

GLWQA Annex(es):

IJC Desired Outcome(s): 5: Economic viability

GLFC Objective(s):

Beneficial Use Impairment(s):



## Energy Use

### Indicator ID: 7057

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#### **Measure**

Energy use in kilowatt hours per capita

#### **Purpose**

To directly measure the amount of energy consumed in the Great Lakes basin and to indirectly measure the demand for resources from the ecosystem, as well as the levels of pollution and other associated negative impacts on the ecosystem. Energy consumption is a good proxy for resource use, waste and pollution creation, and ecosystem stress.

#### **Ecosystem Objective**

Sustainable development is a generally accepted goal in the Great Lakes basin. This indicator supports Annex 1 and 15 of the GLWQA.

#### **Endpoint**

Resource conservation minimizing the unnecessary use of resources is an endpoint for ecosystem integrity and sustainable development.

#### **Features**

The indicator is useful on a state/province/country basin basis. The trend for energy use has been increasing over time, which this indicator will depict as it tracks annual energy use.

#### **Illustration**

The indicator will be shown as a measure of kilowatt hours electrical energy used per capita.

#### **Limitations**

While the data are readily abundant for electrical energy, it will be more difficult to assess other energy sources such as hydrocarbon used in transportation, wood burned in fireplaces, natural gas and furnace fuels. This will require considerable effort.

#### **Interpretation**

Energy is a key aspect of ecosystem sustainability. The second law of thermodynamics is a starting point to understanding the way in which energy plays a key role in long term sustainability. Reducing the use of energy of all kinds will reduce 'entropy' and ensure a more sustainable future. Although electrical energy is a good proxy for total energy use, a complete accounting of all energy used is desirable. Although all forms of energy should be considered for conservation, electrical energy is used as a proxy.

#### **Comments**

Canada and the United States are among the highest energy consuming nations on Earth.

The indicator provides a quantitative measure of the rate at which non-renewable natural resources are being used up and that renewables are being consumed.

#### **Unfinished Business**

- < Need to develop a more quantitative endpoint.
- < Need to determine how this indicator will be presented - as a graph, on a map, etc?
- < Need to develop a baseline or reference value to be used in assessing whether energy use is increasing or decreasing over time.

#### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): humans

Related Issue(s): stewardship

SOLEC Grouping(s): land use, societal

GLWQA Annex(es):

IJC Desired Outcome(s): 5: Economic viability

GLFC Objective(s):

Beneficial Use Impairment(s):

# Wastewater Pollutant Loading

## Indicator ID: 7059

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### **Measure**

Loadings of metals, BOD and organic chemicals that are released by municipal sewage treatment plants and industrial direct dischargers, into water courses in the Great Lakes basin.

### **Purpose**

To directly measure loadings of wastewater pollutants discharged into the Great Lakes basin and to indirectly measure inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

### **Ecosystem Objective**

Sustainable development and healthy ecosystems through support for Annexes 1 and 8 of the GLWQA.

### **Endpoint**

High quality wastewater discharges that approach the ambient quality of the 'sink' they are being discharged to (or the source from which they originated) is a desired endpoint that can best be achieved through pollution prevention and resource conservation.

### **Features**

Pollutant loadings in wastewater represent waste from land use activities that contaminate the Great Lakes. SOLEC '96 Land Use Background paper discusses the levels of wastewater loading to the Great Lakes. This indicator is related to indicator #7056 Water Use since the quality of wastewater effluent is generally improved in total loadings when the hydraulic volume of wastewater is reduced.

### **Illustration**

The indicator will be presented as graphs that display loadings over time by jurisdiction, by lake basin and for the overall basin.

### **Limitations**

Although data are largely available, they are not collected on a necessarily comparable fashion for both the U.S. and Canada. Some work is required to ensure that Ontario data is consistent with the U.S. Since much industrial wastewater flows to municipal sewage treatment facilities the efficiency of these in reducing waste can be hidden.

### **Interpretation**

Wastewater treatment is dependant on the quality of incoming wastewater sources, the state of the technology to process the wastewater and other factors such as fugitive leaks that can increase volumes dramatically at certain times and result in deterioration of the quality of wastewater. The number of hours of by-pass at wastewater plants may be added as another measure, although this addresses the state of the treatment infrastructure more than waste reduction itself. A historical reference of loadings will be used as a benchmark for the indicator.

### **Comments**

#### **Unfinished Business**

< Need to determine from where in the Great Lakes basin the information will be collected and how frequently.

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): water

Related Issue(s): toxics

SOLEC Grouping(s): nearshore waters, land use

GLWQA Annex(es): 11: Surveillance and monitoring, 12: Persistent toxic substances

IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s):

# Solid Waste Generation

## Indicator ID: 7060

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### **Measure**

Amount of solid waste generated per capita (tons and cubic meters).

### **Purpose**

To directly measure the amount of solid waste generated per capita per capita in the Great Lakes basin and to indirectly measure inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

### **Ecosystem Objective**

Sustainable development is a generally accepted goal for Great Lakes basin society. This indicator supports Annex 1, 12 and 13 of the GLWQA.

### **Endpoint**

The reduction of waste to levels achieved in some European and Asian nations.

### **Features**

Solid waste is generated and deposited on land or is incinerated and the residue remains on the land while other contaminants are redistributed by air and water sources. Solid waste represents a significant portion of all human land activities that generate waste and pollution and is stressful to the ecosystem. The indicator represents waste that goes to hazardous and non-hazardous landfills, as well as incinerators. Annual rates of waste generation will be presented by this indicator and bi-annual reporting will be useful.

### **Illustration**

The indicator will be displayed as tons (tonnes) and cubic meters per capita in jurisdictions and for the basin over time. The indicator will be for all solid wastes over time.

### **Limitations**

Although data are available for all jurisdictions, this indicator will require data coordination and integration. Variability in waste stream composition will result in the need for different types of measurement, such as weight versus volume, and may produce conflicting indications of progress. Regardless of the manner of disposal, the measure should consider the total volume of disposed solid waste. Therefore, important land contamination issues, such as acres of land fill space, will not be dealt with in this indicator.

### **Interpretation**

Solid waste provides a measure of the inefficiency of human land based activities and the degree to which resources are wasted by the creation of waste. Reducing volumes of solid waste are indicative of a more efficient industrial ecology and a more conserving society. Reduced waste volumes are also indicative of a reduction in contamination of land through landfilling and incineration and thus reduced stress on the ecosystem.

### **Comments**

Canada and the U.S. are among the highest waste producers on Earth. Reuse and recycling are opportunities to reduce solid waste levels.

### **Unfinished Business**

- < Need to determine a specific endpoint.
- < Need to determine a baseline value to use for assessing positive or negative trends in the amount of solid waste generated?

### **Relevancies**

Indicator Type: human activity  
Environmental Compartment(s): humans  
Related Issue(s): stewardship  
SOLEC Grouping(s): land use, societal  
GLWQA Annex(es):  
IJC Desired Outcome(s): 5: Economic viability  
GLFC Objective(s):  
Beneficial Use Impairment(s):

# Habitat Fragmentation

## Indicator ID: 8114

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### **Measure**

The pattern of natural habitat remaining within ecoregions/subsections, as measured by 1) area to perimeter ratio; 2) habitat patch size; and 3) percent intact cover.

### **Purpose**

To directly measure the amount and distribution of natural habitat remaining within Great Lakes ecoregions and to indirectly measure the effect of human land uses such as housing, agriculture, flood control, and recreation on habitat needed to support fish and wildlife species.

### **Ecosystem Objective**

Each LaMP is likely to contain objectives that address maximizing the amount of land cover adjacent to the lake. This indicator also relates to the IJC Desired Outcome 6: Biological Community Integrity and Diversity.

### **Endpoint**

The Framework on Guiding Habitat Rehabilitation in Great Lakes Areas of Concern (Environment Canada et al. 1998) suggests specific marsh and forest patch sizes that are required to support various species. For example, 200 hectares of forest patch is required for successful interior forest bird breeding. A total area with more than 70% intact cover is needed for birds.

### **Features**

This indicator will present trends in remaining natural habitat within ecoregions/subsections over time. Sufficient parcels of natural habitat are necessary to support wildlife activities such as breeding and migration. For example, lack of interior forest habitat adversely impacts the reproduction of breeding birds. Loss of natural habitat also adversely impacts migrating birds that need to touch down to refuel on their treks north and south. For some threatened species, there is insufficient habitat to sustain populations.

### **Illustration**

Using GIS, habitat patch size and percent intact cover can be graphically displayed on a map. Calculations to determine area to perimeter ratio could be done on a GIS using a specially designed algorithm. Although illustrating area to perimeter ratio is more difficult, it would be possible to highlight all patches with a desirable ratio on a GIS map once calculations are complete.

### **Limitations**

Although “intact cover” most likely means natural vegetation, primarily forest, there is a need to define this term. The relationship, for example, between the three endpoints — percent intact cover, patch size and perimeter to area ratio — and bird breeding is better understood than the relationship between the endpoints and bird migration. A better understanding of how these endpoints affect bird migration is necessary.

### **Interpretation**

Additional research is needed to understand how much habitat is required in a particular ecoregion for different species and for different functions.

### **Comments**

As suggested, the amount of habitat required for breeding birds is known, but less is known about the amount of natural vegetation required for migrating birds. The requirements for other species will be just as challenging. Information for this indicator can be collected using remote sensing products.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): land

Related Issue(s): habitat

SOLEC Grouping(s): nearshore terrestrial, land use

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

## Streamflow

### Indicator ID: 8142

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#### **Measure**

Streamflow and suspended sediments at the mouth of major tributaries and connecting channels.

#### **Purpose**

To directly measure the amount of water entering the Great Lakes through major tributaries and connecting channels, and to indirectly measure the amount of sediment available for transport to nourish coastal ecosystems.

#### **Ecosystem Objective**

Relates to IJC Desired Outcomes 6: Biological community Integrity and Diversity, and 9: Physical Environmental Integrity.

#### **Endpoint**

Functioning longshore transport process necessary for healthy coastal ecosystems.

#### **Features**

The role of streamflow in sediment transport and nourishment of coastal ecosystems is needed to evaluate and predict the health of the ecosystems. Data for the streamflow and suspended sediments to the lakes from the largest tributaries and for the total combined flow for each lake will be collected every three years. Trends will indicate a change in the amount of sediments available for coastal nourishment. Monitoring of streamflow and sediment load is one of the oldest and most well established programs in both the United States and Canada.

#### **Illustration**

Data for the streamflow and suspended sediments to the lakes from the largest tributaries and for the total combined flow for each lake will be depicted as line graphs.

#### **Limitations**

Recent dramatic cuts in the Canadian budget may influence this monitoring. An evaluation is needed to prioritize the location of monitoring locations.

#### **Interpretation**

Once baseline values are determined, streamflow at the mouths of specified tributaries and concentration of suspended sediments will be tracked.

#### **Comments**

Data may be eventually used to help evaluate the impacts of climate change.

#### **Unfinished Business**

- < Need to provide a unit of measurement to increase specificity.
- < Need to determine a quantifiable endpoint.

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): water, sediments

Related Issue(s): habitat

SOLEC Grouping(s): nearshore waters, coastal wetlands, nearshore terrestrial

GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of phosphorus, 11: Surveillance and monitoring, 12: Persistent toxic substances, 13: Pollution from non-point sources, 17: Research and development

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 8: Eutrophication or undesirable algae, 14: Loss of fish and wildlife habitat

# Breeding Bird Diversity and Abundance

## Indicator ID: 8150

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### **Measure**

Diversity and abundance of breeding bird populations and communities in selected habitat types, and an avian index of biotic integrity.

### **Purpose**

To directly measure the status of breeding bird populations and communities and to indirectly measure the health of breeding bird habitat in the Great Lakes basin.

### **Ecosystem Objective**

Relates to IJC Desired Outcome 6: Biological Community Integrity and Diversity.

### **Endpoint**

For this indicator, the desired outcome would vary by species and habitat type. A target of no decline in area-sensitive bird species (forest/grasslands/savannah) could be established for a select group of species within each habitat type being sampled. A target of increasing populations of contaminant-sensitive bird species in coastal breeding territories could also be established and monitoring protocols designed to assess attainment. A target of 90% of the monitoring stations achieving species presence equal to 90% of the expected number based on habitat and range could be a third type of desired outcome.

### **Features**

The Great Lakes Basin supports a rich diversity of breeding bird species. This region is one of the most important regions on the North American continent for abundance and diversity of breeding birds. 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. Because breeding birds are strongly linked to habitat conditions, this indicator has potential to have cross applications to other wildlife taxa and other indicators.

An "index of biotic integrity" has been used successfully in other areas and while its application to bird communities is in the experimental stages, it should be considered. For this approach to be successful across the Great Lakes basin, reference areas with healthy bird communities would be identified and compared with other, potentially less healthy areas. Commonly-used indices of diversity (e.g., species richness, Shannon-Weiner, Simpson's) could be used to describe the health of the bird community in selected habitat types and could be tracked over time.

### **Illustration**

Data from this indicator could be presented in a variety of ways. Population status and trends for bird species of interest could be illustrated by simple line graphs representing selected geographic areas or the whole basin. Comparison graphs showing area sensitive forest bird species and species pre-adapted to highly modified landscapes could be used to show effects of land use changes across the basin. Indices of biotic integrity for areas surveyed would be presented in bar graph form and compared to other areas for which the index has been calculated. Broader scaled biodiversity patterns across the Great Lakes basin could be presented in map form that identify key habitat areas (biodiversity investment areas, protected areas, biodiversity hot spots). These maps could also be used to illustrate changes in bird population patterns over time.

### **Limitations**

Confidence in using these data to express the health of a large-scale, diverse ecosystem, would depend on having site specific data that adequately represented the range of habitat conditions in the region. For example, relying only on bird monitoring activity in National Parks, where disturbance and fragmentation of habitat is likely low, could result in overly optimistic pictures of population trends or ecosystem health. Conversely, reliance on data from easily accessible areas such as road-side counts, could lead to indices that suggest conditions are worse than they really are. Data gathering for this indicator is personnel intensive during the short, early-summer breeding season. To adequately survey the Great Lakes basin will require large numbers of trained staff and substantial travel expenses.

### **Interpretation**

Changes in abundance, density, and productivity 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. Utilizing information from ongoing research and management on migration routes and wintering areas will be essential for interpreting these data.

### **Comments**

Populations and communities of birds have been used to indicate a wide variety of ecological stressors and processes. Birds are abundant in many habitat types. They make up about 70% of the terrestrial vertebrate species in Great Lakes forests for example. Understanding population dynamics and habitat associations of breeding birds will aid in understanding major elements of ecosystem health.

By following a consistent protocol of 10 minute point counts by highly trained professional bird surveyors, stratifying points by habitat, prioritizing habitats to be surveyed, and conducting surveys only on rain-free, calm days, compatible data can be collected by many researchers and agency staff. Substantial agreement and consistency has already been achieved on survey methodology by researchers across the Great Lakes basin.

Habitat analysis and landscape assessment of the Great Lakes Basin (see habitat cover indicators) would allow a monitoring protocol to be developed that would identify priority habitat types. It would also allow a stratified, random sampling design, based on relative area of habitat types to be developed. This would provide a more valid, robust and geographically integrated monitoring program than what now exists. Monitoring efforts ongoing in several National Forest (Superior, Chequamegon) and National Parks (Apostle Islands, Isle Royale) and the USF&W Service's Breeding Bird Survey can be used to take model elements for developing this indicator. The Ontario Forest Bird Monitoring Program and Marsh Monitoring Program also provide site-specific data which could be integrated into this indicator. A Great Lakes Basin-wide monitoring protocol for gathering habitat-specific information on the status and trends of bird populations and communities, coordinated with systematic, landscape-scale vegetation data will allow basin-wide biodiversity mapping based on bird populations. For most habitat types and bird taxa, monitoring is most efficient when survey data on all singing birds are collected. Multiple indices of ecosystem health can then be calculated based on data gathered.

This indicator allows interpretation at multiple scales. 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. Comparisons of indices of biotic 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.

Expansion of ongoing monitoring and efforts to standardize data gathering and quality control would be one way to approach the development of this indicator with the funds that might realistically be expected.

### ***Unfinished Business***

#### ***Relevancies***

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s):

SOLEC Grouping(s): unbounded

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

## Threatened Species

### Indicator ID: 8161

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#### **Measure**

Number, extent, and viability of species ranked as G1-G3 or S1-S3 in the Biological Conservation Database. A global or "G" rank is assigned on the basis of relative endangerment based primarily on the number of occurrences of the element globally. A rank of G1 means critically imperiled globally due to extreme rarity or due to factor(s) making it very vulnerable to extinction. A rank of G2 means imperiled globally due to rarity or due to some factor(s) making it very vulnerable to extinction throughout its range. A rank of G3 means either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range or due to other factors making it vulnerable to extinction throughout its range. A state or "S" rank focuses on the status of a species or ecosystem within the boundaries of a state. A rank of S1 means critically endangered with less than five known occurrences. A rank of S2 means six to twenty occurrences which are to some extent threatened. A rank of S3 means very rare or local throughout its range.

#### **Purpose**

To directly measure the number, extent and viability of threatened species, key components of biodiversity in the Great Lakes basin, and to indirectly measure the ecological integrity of processes and systems (e.g., sand accretion, hydrologic regime) within Great Lakes habitats.

#### **Ecosystem Objective**

Healthy populations of all vegetation and wildlife, including the rarest of species. Relates to IJC Desired Outcome 6: Biological Community Integrity and Diversity.

#### **Endpoint**

Viable populations of G1-G3 or S1-S3 species that are stable and persistent over the long term, even though local populations may fluctuate significantly in time and space.

#### **Features**

The rarest species of an ecosystem are indicators of the health of and stresses on the ecosystem. This indicator would emphasize vascular plants for ease of sampling, and would include wildlife to the extent possible. Optimum sampling methods would need to be determined. Representative areas of large size (e.g. 10 km x 10 km square with appropriate habitat) would be selected with ecological subdivisions supporting the species, and sampled at 2-5 year intervals at coarse and fine scales to document locations, aerial extent, and numbers target species. Sampling area size and timeline for trend analysis might vary by species, depending on the habitat and life history. Comparison of successive sampling results would be used to identify short and long term trends. It would be important to select sampling areas that are ecologically relatively intact, as well as some with varying degrees of observable human impact.

#### **Illustration**

Graphs of population numbers for each target species over time per sampling site, ecoregion, and basin-wide.

#### **Limitations**

It would be costly to annually monitor all populations of all species. A subset could be sampled annually, to determine trends that might be applicable to the entire set. Certain species are more sensitive to change than others.

#### **Interpretation**

Natural environments are dynamic by nature, therefore, local decreases or even extirpations of a threatened species may be normal. On the other hand, local extirpations can also be linked to human alterations of habitats through activities such as development. Measures will need to be interpreted with contextual information on anthropogenic disturbances, and need to be taken over sufficient space and time to generate a "big picture" of metapopulations in contiguous or semi-contiguous habitats. Overall stability or increases in viable populations indicates integrity of key supporting processes to which the species are adapted. Overall decreases in population numbers and/or extent can signal deterioration of key processes that maintain suitable habitat.



**Comments**

Experts from the states/provinces should collectively decide which species would be the best indicators. Using the ranking system from the Biological Conservation Database provides a more uniform assessment of status across jurisdictions, and provides access to an existing digital database.

**Unfinished Business**

< Need to provide quantitative values for “viable populations.”

**Relevancies**

Indicator Type: state

Environmental Compartment(s): biota, fish

Related Issue(s): exotics, habitat

SOLEC Grouping(s): open waters, nearshore waters, coastal wetlands, nearshore terrestrial, land use

GLWQA Annex(es): 11: Surveillance and monitoring, 17: Research and development

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

# Fecal Pollution Levels of Nearshore Recreational Waters

## Indicator ID: 4081

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### **Measure**

1) Counts of fecal coliforms (FC) and/or E.coli in recreational waters measured as number of organisms per volume of water (e.g., FC/ml); and 2) frequency of beach closings at specific locations.

### **Purpose**

To directly measure fecal coliform and E. coli levels in nearshore recreational waters, and as a surrogate indicator for other pathogen types, to indirectly measure potential harm to human health through body contact with nearshore recreational waters.

### **Ecosystem Objective**

Waters should be safe for recreational use. Waters used for recreational activities involving body contact should be substantially free from pathogens, including bacteria, parasites, and viruses, that may harm human health. This objective is consistent with Desired Outcome #2, Swimmability, identified in the IJC document Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement 1996.

### **Endpoint**

Fecal coliform and E. coli levels should not exceed national, state, and/or provincial standards set for recreational waters.

### **Features**

One of the most important factors in nearshore recreational water quality is that it be free from microbial contamination. Recreational waters may become contaminated with animal and human feces from sources and conditions such as combined sewer overflows that occur in certain areas after heavy rains, agricultural run-off, and poorly treated sewage. 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.

### **Illustration**

For each site selected throughout the basin, a bar graph will be presented showing the counts of fecal coliform and E. coli over several years. Statistical analysis will be used to examine the temporal and spatial trends in water quality in recreational beach areas. Data will be presented as a bar graph or as a GIS map showing the number of beach closings over time.

### **Limitations**

Variability in the data from year to year may result from the process of monitoring and variations in reporting, and may not be solely attributable to actual increases or decreases in levels of microbial contaminants. Viruses and parasites, although a concern in recreational waters, are difficult to isolate and quantify at present, and feasible measurement techniques have yet to be developed. Comparisons of the frequency of beach closings will be limited due to use of different water quality criteria in different localities.

### **Interpretation**

This indicator will rely on national, state, and/or provincial fecal coliform or E. coli standards as a benchmark. Trends that demonstrate an increase in fecal pollution levels over time, and above the appropriate standard, will be considered negative, or bad, trends. Trends that demonstrate a decrease in fecal pollution levels over time, and below the appropriate standard, will be considered positive, or good, trends.

### **Comments**

Analysis of data may show seasonal and local trends in recreational water. 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.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): water

Related Issue(s): toxics, nutrients

SOLEC Grouping(s): nearshore waters, human health

GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 2: Swimmability, 4: Healthy human populations

GLFC Objective(s):

Beneficial Use Impairment(s): 10: Recreational water impairment

# Chemical Contaminants in Fish Tissue

## Indicator ID: 4083

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### **Measure**

Concentration of PBT chemicals targeted by the GLWQA in edible fish tissue.

### **Purpose**

To directly measure the concentration of PBT chemicals in Great Lakes fish and to indirectly measure the exposure of humans to PBT chemicals through consumption of Great Lakes fish caught via sport and subsistence fishing.

### **Endpoint**

Reduction in concentration of PBT chemicals in fish tissue to levels that do not pose a risk to populations consuming Great Lakes fish. The elimination of fish advisories in the Great Lakes may be considered to be an appropriate endpoint.

### **Ecosystem Objective**

Fish in the Great Lakes ecosystem should be safe to eat; consumption should not be limited by contaminants of human origin. This objective is consistent with Desired Outcome #1, Fishability, identified in the IJC document Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement (1996).

### **Features**

The temporal and geographic trends in the chemical contaminant levels in fish species consumed by human populations in the Great Lakes basin will be used as an indicator of exposure to PBT chemicals. Concentrations of contaminants in fish should be determined from a boneless, skinless fillet of dorsal muscle flesh removed from the fish. This would provide not only the most consistent test results, but is also the most edible portion of the fish. Choosing appropriate indicator species is crucial and should be based on fish consumption patterns and availability of data. Additional chemicals can be considered as new information arises. The indicator will allow regulatory agencies to make suggestions regarding remedial planning as well as issuing advisories to the public on safe consumption limits.

### **Illustration**

Results of raw data will be used to construct simple bar graphs showing the fluctuation of contaminants over time and space.

### **Limitations**

Data for use in developing indicators exist, however, there are differences in surveillance techniques for fish consumption and differences in tissue sampling methods between jurisdictions.

### **Interpretation**

Reductions in contaminant levels in fish tissue will reflect an improvement in environmental quality and the potential for reduced exposure to contaminants from consumption of Great Lakes fish.

### **Comments**

### **Unfinished Business**

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): fish

Related Issue(s): toxics

SOLEC Grouping(s): open waters, nearshore waters, human health

GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances

IJC Desired Outcome(s): 1: Fishability, 4: Healthy human populations, 6: Biological community integrity and diversity

GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior

Beneficial Use Impairment(s): 1: Restrictions on fish and wildlife consumption

# Chemical Contaminant Intake from Air, Water, Soil and Food

## Indicator ID: 4088

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### **Measure**

Estimated total daily intake of PBT chemicals targeted by the GLWQA from air, water, soil, and food sources.

### **Purpose**

To estimate the daily intake of PBT chemicals from all sources and to indirectly estimate the potential harm to human health and the efficacy of policies and technology intended to reduce PBT chemicals.

### **Ecosystem Objective**

Relates to IJC Desired Outcome 7: Virtual elimination of inputs of persistent toxic substances

### **Endpoint**

Intake of PBT chemicals from all sources should be below established guideline values and should continue to decline.

### **Features**

This indicator tracks contaminants levels in various media and their estimated daily intake via ingestion and inhalation. 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 (Great Lakes Health Effects Program, Health Canada). Estimated daily intakes can be updated periodically, as new data becomes available.

### **Illustration**

The temporal variation in estimated dose for each age group and the relative contribution of each media as a percentage of total dose will be displayed in a graphic format.

### **Limitations**

Factors such as technological advances, differences in sampling and laboratory procedures, as well as survey questionnaires, create difficulties in accurately comparing historical data.

### **Interpretation**

Changes in the estimated daily dose from air, water, soil or food sources will indicate changes in environmental quality, in human exposure, and the risk to human health.

### **Comments**

### **Unfinished Business**

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): humans

Related Issue(s): toxics

SOLEC Grouping(s): human health

GLWQA Annex(es): 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development

IJC Desired Outcome(s): 4: Healthy human populations

GLFC Objective(s):

Beneficial Use Impairment(s):

# Drinking Water Quality

## Indicator ID: 4175

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### **Measure**

Concentrations of chemical substances such as alkylphenols, metals (e.g., lead, mercury) and other inorganic compounds, pesticides, radionuclides, and drinking water disinfection by-products (e.g., trihalomethanes) as well as microbial parameters such as bacteria, viruses and parasites in raw, treated and distributed drinking water.

### **Purpose**

To directly measure chemical and microbial contaminant levels in drinking water and to indirectly measure potential for human exposure to drinking water contaminants, as well as to indirectly measure the efficacy of policies and technologies to ensure safe drinking water.

### **Ecosystem Objective**

Treated drinking water supplies should be safe to drink. This objective is consistent with Desired Outcome #3, Drinkability, identified in the IJC document Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement (1996).

### **Endpoint**

Densities of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances should not exceed human health objectives, standards, or guidelines.

### **Features**

This indicator would reveal trends in contaminant levels in raw, treated and distributed water in various locations throughout the basin. Through existing water monitoring programs, which analyse raw, treated and distributed waters, results can be compared against established water quality objectives. This evaluation applies to water supply systems that draw water from either surface water or groundwater sources. Data on temporal trends, such as seasonal differences or changes over time, in chemical or microbial contaminant concentrations for specific locations could be identified.

### **Illustration**

For selected locations in the Great Lakes basin, simple bar or line graphs would display the average concentration of contaminants in raw, treated and distributed water. The data could also be displayed in a GIS format that would allow for a variety of endpoint analyses to be displayed as an overlay on maps of the entire Great Lakes basin or more local areas.

### **Limitations**

Most contaminants in drinking water rarely exceed guidelines and many are below their analytical detection limit. Since the absolute concentration of some contaminants may not be determinable, it is difficult to show fluctuations in their concentration levels.

### **Interpretation**

Existing monitoring programs at drinking water treatment plants analyse for chemical and microbial contaminants in raw, treated and distributed waters. Results can be compared against established water quality guidelines and objectives. The data could be supplemented with additional information showing relationships between contaminant levels and human health risks; for example, the association between long-term exposure to chlorination disinfection by-products in drinking water and the increased risk of bladder and colon cancers.

### **Comments**

### **Unfinished Business**

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): water

Related Issue(s): toxics, nutrients

SOLEC Grouping(s): nearshore waters, human health

GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 16: Pollution from contaminated groundwater

IJC Desired Outcome(s): 3: Drinkability, 4: Healthy human populations, 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 9: Restrictions on drinking water consumption or taste and odor problems

## Air Quality

### Indicator ID: 4176

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#### **Measure**

Concentration of chemicals and particulate matter in ambient air.

#### **Purpose**

To directly monitor the air quality in the Great Lakes ecosystem and to indirectly measure the potential impact of air quality on human health in the Great Lakes basin; in addition, to indirectly measure the potential impact of inefficiencies in human economic and land use activities on air quality.

#### **Ecosystem Objective**

Air should be safe to breathe. Air quality in the Great Lakes ecosystem should be protected in areas where it is relatively good, and improved in areas where it is degraded. This is consistent with ecosystem objectives statements being adopted by certain lakewide management plans, including Lake Superior, (Ecosystem Principles and Objectives, Indicators and Targets for Lake Superior, Lake Superior Binational Program, 1995), in fulfilment of Annex 2 of the Great Lakes Water Quality Agreement.

#### **Endpoint**

Canadian and U.S. air quality standards.

#### **Features**

The Great Lakes basin experiences high levels of certain air pollutants due to both local sources and long range transport. Studies conducted in the Great Lakes region have provided strong evidence linking ground-level ozone and sulphates to increased rates of hospital admissions for cardiorespiratory disease and to increased death rates. Pollutants that can be used to assess overall air quality include SO<sub>2</sub>, CO, O<sub>3</sub>, NO<sub>x</sub>, TRS and SP. Air toxics, such as benzene, formaldehyde, and ethylene dichloride, should also be used to assess air quality. Other air pollutants can be added as new information becomes available. This indicator can use information from existing air monitoring databases. Data can be supplemented with established associations between levels of ambient air pollution and rates of admissions to acute care hospitals for cardiorespiratory disease.

#### **Illustration**

Using a GIS mapping display, trends in pollutant levels over several years for each pollutant in a particular region or over the entire Great Lakes basin data could be presented. Data could also be displayed as the number of exceedances of guidelines which may be established for any pollutant. The above data could be supplemented with additional graphs showing the relationships between sulphate and ozone levels in outdoor air and hospital admissions for cardiorespiratory diseases.

#### **Limitations**

Canadian and U.S. jurisdictions employ different standards for measurement of exceedances. Although indoor air is a major contributor to exposure to air toxics, there is no practical way to consistently monitor indoor air quality. Therefore, this component to the estimate of total exposure to airborne contaminants will not be included in this indicator.

#### **Interpretation**

Interpretation of the indicator would be made by identifying trends in the levels of air contaminants over time in comparison to guideline levels.

#### **Comments**

A significant association is found between atmospheric ozone and sulphate levels and the number of daily hospital admissions for respiratory conditions. Five percent of daily respiratory admissions in the months of May to August can be attributed to ozone, and an additional 1% to sulphates. This finding is consistent among all age groups. The largest impact appears to be on children under 2 years of age, in whom 15% of respiratory hospital admissions are attributed to ozone and sulphate together, while the elderly are least affected (4%). There does not appear to be a level of ozone below which no adverse respiratory health effects are observed.

For both respiratory and cardiac illnesses, the average daily hospitalization rates increase with increasing levels of sulphates. A 13 ug/m<sup>3</sup> increase in sulphates recorded on the previous day is associated with a 3.7% increase in respiratory admissions and a 2.8% increase in cardiac admissions. Admissions for cardiac diseases increases 2.5% for those under 65 years and 3.5% for those 65 years and older.

Some air pollution emissions can be prevented through better pollution prevention or by changing the demand for certain products and services that contribute to air pollution. Therefore, this indicator can additionally measure progress on

sustainable development by determining the degree to which resources are wasted as pollution, thereby representing inefficiency in human economic activity.

### ***Unfinished Business***

#### ***Relevancies***

Indicator Type: pressure

Environmental Compartment(s): air

Related Issue(s): toxics

SOLEC Grouping(s): human health

GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 4: Healthy human populations

GLFC Objective(s):

Beneficial Use Impairment(s):

# Chemical Contaminants in Human Tissue

## Indicator ID: 4177

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### **Measure**

Concentrations of PBT chemicals targeted by the GLWQA in human tissues such as blood, breast milk, hair and adipose tissues.

### **Purpose**

To directly measure the concentration of PBT chemicals in human tissues and to indirectly measure the efficacy of policies and technology to reduce PBT chemicals in the Great Lakes ecosystem.

### **Ecosystem Objective**

This indicator relates to IJC Desired Outcome 4: Healthy Human Populations.

### **Endpoint**

Continued reduction of PBT chemical concentrations in human tissue. Where PBT chemicals are detected, they should be maintained below health guidance levels.

### **Features**

This indicator will monitor the concentration of PBT chemicals in human tissues to establish geographic patterns and trends over time, providing an estimate of both past and current chemical exposures.

### **Illustration**

Data will be displayed as bar graphs showing PBT chemical concentrations over time to highlight trends and in GIS format to illustrate geographic patterns in body burden levels.

### **Limitations**

This indicator requires extensive sampling of human populations, as well as standardized tissue collection and chemical analysis methods for use by participating laboratories. A detailed history of the sample population, including diet, lifestyle, and occupation, is necessary to characterize the history of exposure.

### **Interpretation**

The long persistence of PBT chemicals in the body would indicate that there is a relatively long time period between reductions in exposure and subsequent reductions in tissue levels. However, trends that demonstrate a decrease in the concentration of PBT chemicals in human tissue, to levels below health guidance levels, would be a positive indication that the human health risks posed by exposure to environmental contaminants are being reduced. Tissue levels above health guidance values are a concern for human health.

### **Comments**

### **Unfinished Business**

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): humans

Related Issue(s): toxics

SOLEC Grouping(s): human health

GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development

IJC Desired Outcome(s): 4: Healthy human populations, 7: Virtual elimination of inputs of persistent toxic substances

GLFC Objective(s):

Beneficial Use Impairment(s):



# Radionuclides

## Indicator ID: 4178

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### **Measure**

Concentration of Cs-137 and Sr-90 in cow's milk, gross beta activity in air and precipitation, and airborne and waterborne radionuclide emissions from nuclear power plants in the Great Lakes basin.

### **Purpose**

To directly measure concentrations of artificial radionuclides in cow's milk, surface water, drinking water, and air, and to indirectly estimate the potential for human exposure to artificial radionuclides.

### **Ecosystem Objective**

This indicator relates to IJC Desired Outcome 4: Healthy Human Populations.

### **Endpoint**

Limit releases of artificial radionuclides to minimize human exposure.

### **Features**

This indicator will provide a measure of the overall exposure of the Great Lakes basin population from nuclear weapons fallout. It will present almost 30 years of data on the concentration of cesium-137 and strontium-90, two types of radionuclides associated with above ground nuclear weapons testing, in cow's milk and gross beta activity in air and precipitation since cessation of atmospheric weapons testing. This indicator will also present trends in the concentrations of airborne and waterborne tritium, strontium-90, iodine-131, cesium-134, and cesium-137 emissions from nuclear power plants in the Great Lakes basin, providing an estimate of exposure to contaminants from nuclear power plant discharges. Measurements of radionuclide emissions may allow for the estimation of human exposure to discharges by nuclear power plants and may indicate geographical differences in exposure from those sources. In addition to natural background radiation, the Great Lakes basin contains nearly all components of the nuclear fuel cycle, as well as many radioisotope users such as hospitals and industry.

### **Illustration**

Graphs will display almost 30 years of data on the concentration of cesium-137 and strontium-90 in cow's milk and gross beta activity in air and precipitation. Graphs will also present reported airborne and waterborne tritium, strontium-90, iodine-131, cesium-134, and cesium-137 emissions from nuclear power plants in the Great Lakes basin, beginning in 1972 (ref. IJC Nuclear Task Force, 1997).

### **Limitations**

Monitoring of radionuclides in the Great Lakes basin meets primarily the compliance needs of licenses for discharge. Very little of the current monitoring activities are designed to address, or are capable of considering, the movement and cycling of radionuclides through environmental compartments and ecosystems. The data for Cs-137 and Sr-90 concentrations collected during the past 30 years show a decline in radioactivity in the Great Lakes basin after the ban on above ground nuclear weapons testing. The trend illustrated by these data— decreased exposure to Cs-137 and Sr-90 due to decreased weapons testing— is not especially useful to policy makers and regulatory agencies.

### **Interpretation**

A trend of decreasing concentration of artificial radionuclides over time would indicate a reduction in risk to human health. A trend of increasing concentrations would indicate a potential for greater human exposure.

### **Comments**

Hypothetical estimates based on conservative exposure models estimates the total number of fatal cancers, non-fatal weighted cancers, and hereditary disorders over the lifetime of the current Canadian Great Lakes basin population attributable to a 50-year exposure to natural background radiation is of the order of 340,000. The total number of health effects attributable to radioactive fallout from all the weapons tests to date would be in the order of 5,000. Health Effects due to 50 years of operation of the nuclear fuel cycle at current levels would be of the order of 200. (Ref. Health Canada, State of Knowledge Report on Environmental Contaminants and Human Health in the Great Lakes Basin, 1997). On average, natural radiation accounts for more than 98% of human exposure to ionizing radiation, excluding medical exposures.

### **Unfinished Business**

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): air, water

Related Issue(s): toxics

SOLEC Grouping(s): human health

GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 17: Research and development

IJC Desired Outcome(s): 4: Healthy human populations

GLFC Objective(s):

Beneficial Use Impairment(s):

# Geographic Patterns and Trends in Disease Incidence

## Indicator ID: 4179

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### **Measure**

Disease incidence rate (rate = number of new cases of specific disease/ size of population) for those diseases that have a demonstrated environmental link, such as cancers and birth defects, in the Great Lakes basin.

### **Purpose**

To directly measure disease incidence rates in the Great Lakes basin population and to assess areas in the Great Lakes basin where further investigation of the exposure and effects of environmental pollutants on human health is needed.

### **Ecosystem Objective**

This indicator relates to IJC Desired Outcome 4: Healthy Human Populations.

### **Endpoint**

Disease incidence rates should decrease over time. Environmental pollutants should be minimized as health risk factors.

### **Features**

This indicator provides geographical and temporal patterns of disease incidence, such as cancer and birth defects, throughout the Great Lakes basin. Although cause and effect relationships cannot be established from this indicator, it is useful for identifying areas that may require investigation.

### **Illustration**

This indicator is represented by maps of the Great Lakes basin illustrating the distribution of disease incidences, such as cancers and birth defects, in Ontario. In addition, a graph will show trends in the incidences of diseases over time.

### **Limitations**

The accuracy of this indicator depends on the availability and quality of hospital records and continuing improvements of registry databases. Cause and effect relationships between environmental conditions and disease incidence rates cannot be established from this indicator. The explanation of disease incidence rates, such as cancer and birth defects, in any area requires more extensive epidemiological research to assess the relative importance of various factors, including diet, lifestyle, occupation, and exposure to environmental contaminants.

### **Interpretation**

Although cause and effect relationships between environmental contaminants and disease cannot be established from this indicator, it is useful for identifying areas which require investigation. Additional evaluation will be required to refine the analysis to specific cancers and birth defects that are most likely to be related to environmentally related. This indicator may also allow for the development of new hypotheses regarding the role of environmental exposure in the etiology of human disease.

### **Comments**

This indicator could be expanded in the future to include biomonitors of exposure, biomarkers of pre-disease conditions, endocrine disruption, and low birth weight.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s): humans

Related Issue(s):

SOLEC Grouping(s): human health

GLWQA Annex(es): 17: Research and development

IJC Desired Outcome(s): 4: Healthy human populations

GLFC Objective(s):

Beneficial Use Impairment(s):

# Capacities of Sustainable Landscape Partnerships

## Indicator ID: 3509

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### **Measure**

Number of partnerships; basin location and geographic coverage; budgets, FTE staff; identification of major projects and initiatives.

### **Purpose**

General measures of the number, distribution, and extent of geographic coverage of sustainable landscape initiatives in the Great Lakes basin; description of their basic organizational capacities to implement ecosystem management initiatives.

### **Ecosystem Objective**

A Sustainable Great Lakes Ecosystem.

### **Endpoint**

Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

### **Features**

Identification and survey of Sustainable Landscape Partnerships and a compilation of responses.

### **Illustration**

Graphs, charts, narrative descriptions, and maps; data presented for the Great Lakes basin and cross-broken by individual Lakes; maps indicating coverage of basin(s) by stated partnership boundaries.

### **Limitations**

Some interpretation of definitions is required to set qualifying criteria for sustainable landscape partnerships to determine the sample frame for the survey.

### **Interpretation**

This indicator will show the coverage of the basin(s) by place-based ecosystem management initiatives and provide descriptive information of their capacities to do this work.

### **Comments**

Local collaborative partnerships have the potential to address ecosystem issues that have proven beyond the capacities of existing resource management programs. These issues include such landscape wide objectives as habitat protection, nonpoint pollution, aesthetics, and recreational opportunities. Partnerships may include many actors who have not traditionally seen themselves as significant or important ecosystem managers. These potential partners may include land use and development decision makers, municipal governments, private industries, agriculture, engineering firms, universities, non-profit organizations, community foundations, and others.

### **Unfinished Business**

< Since SOLEC 98 no revisions have been made to this indicator - however, revisions will be made before the next version is released. Comments on this indicator are most welcome.

### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): humans

Related Issue(s): stewardship

SOLEC Grouping(s): societal

GLWQA Annex(es):

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s):

# Organizational Richness of Sustainable Landscape Partnerships

## Indicator ID: 3510

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### **Measure**

The diversity of the members participating in partnerships measured on two axes: Horizontal Integration -- the diversity of local partners; and Vertical Integration -- the direct participation of federal and state/provincial actors in local partnership initiatives.

### **Purpose**

Stewardship is a function of local partners coming together to redefine problems in such a manner as to bridge the gaps between previously insular decision-making processes, e.g., land development, land use controls, water quality management and habitat protection. This redefinition of problems and responses can be enhanced and empowered by the direct participation federal and state/provincial partners. The indicator measures the "richness" of local partnerships along these two dimensions. It focuses on the role of "full partners," those actors who are willing to modify plans, programs, and budgets in support of shared core values pertaining to sustainable landscapes.

### **Ecosystem Objective**

A Sustainable Great Lakes Ecosystem

### **Endpoint**

Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

### **Features**

Horizontal Integration: Measured by surveying identified partnerships as to the range and diversity of participants engaged in full partnership.

Vertical Integration: Measured by surveying identified partnerships as to the collaborative involvement of federal and state/provincial actors as full partners in local initiatives.

### **Illustration**

Graphs, charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

### **Limitations**

Some definition and interpretation will be required to set parameters for "full partners" and to translate the diversity of partners into a simple scalar presentation for each locality and basin.

### **Interpretation**

The description of the base capacities of partnerships to accomplish sustainable landscape initiatives by building collaborative relations between local decision making systems, e.g., the land conversion system: lending institutions, developers, and real estate agents; the description of the extent of participation of federal and state/provincial partners to enhance and empower these local initiatives.

### **Comments**

Ecosystem management initiatives require new constituencies that expand the traditional boundaries of resource management. In addition, Federal, state/provincial, and regional agencies have the greatest expertise and resources to support sustainable ecosystem management. Their presence as full partners in local initiatives brings their expertise and resources to the table to assist in achieving shared goals.

### **Unfinished Business**

< Since SOLEC 98 no revisions have been made to this indicator - however, revisions will be made before the next version is released. Comments on this indicator are most welcome.

### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): humans

Related Issue(s): stewardship

SOLEC Grouping(s): societal

GLWQA Annex(es):

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s):

# Integration of Ecosystem Management across Landscapes

## Indicator ID: 3511

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### **Measure**

Simple reporting of the adoption of ecosystem management as a guiding principle in place-based resource management programs by states/provinces and regional agencies and governments and budget allocations in support of ecosystem management programs and projects.

### **Purpose**

Some state/provincial and regional agencies and governments have formally adopted and provided resources for the implementation of ecosystem management as a basic strategy. Such actions provide the fundamental institutional framework for the development of place-based partnerships for stewardship. This indicator provides an enumeration of these governments and agencies and reports the extent of their institutional support for ecosystem management.

### **Ecosystem Objective**

A Sustainable Great Lakes Ecosystem

### **Endpoint**

Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

### **Features**

Survey of basin and lake governments to identify policies, programs, and agencies for which ecosystem management is a guiding principle and budget allocations in support of these activities.

### **Illustration**

Graphs and charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

### **Limitations**

Some definition and interpretation will be required to set parameters for "adoption of ecosystem management as a guiding principle."

### **Interpretation**

The formal adoption of ecosystem management as an agency strategy combined with an description of the resources allocated for the implementation of the strategy provides a index of institutional commitment to stewardship initiatives.

### **Comments**

Adoption of ecosystem management principles necessarily leads to the identification of interrelationships in landscape systems. An emphasis on these interrelationships requires the completion of ecological risk and functional value assessments as well as community value surveys to determine priorities pertaining to ecosystem health. This process leads to the definition of appropriate action in places.

### **Unfinished Business**

< Since SOLEC 98 no revisions have been made to this indicator - however, revisions will be made before the next version is released. Comments on this indicator are most welcome.

### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): humans

Related Issue(s): stewardship

SOLEC Grouping(s): stewardship

GLWQA Annex(es):

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s):

# Integration of Sustainability Principles across Landscapes

## Indicator ID: 3512

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### **Measure**

Simple reporting of the adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments and budget allocations in support of sustainability initiatives and projects.

### **Purpose**

Some state/provincial and regional agencies and governments have formally adopted place-based sustainability as a fundamental goal for resource management and allocated resources for its achievement. The establishment of such a goal institutionalizes stewardship as a process for place-based partnerships. This indicator provides an enumeration of these governments and agencies and reports the extent of their institutional support for place-based sustainability.

### **Ecosystem Objective**

A Sustainable Great Lakes Ecosystem

### **Endpoint**

Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

### **Features**

Survey of basin and lake governments to identify policies, programs, and agencies that have adopted place-based sustainability as a strategic goal and allocated resources for its achievement.

### **Illustration**

Graphs and charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

### **Limitations**

Some definition and interpretation will be required to set parameters for "adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments."

### **Interpretation**

The formal adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments combined with a description of the resources allocated for its achievement provides a index of institutional commitment to stewardship initiatives.

### **Comments**

Adoption of place-based sustainability principles establishes the balance between economic vitality, environmental health and social well being as a fundamental goal. It also institutionalizes a long term time horizon for ecosystem management activities. Focusing sustainability on landscapes will lead to the establishment of levels of integrity and health and an acknowledgment that functioning and inter-related systems are required to maintain this health and integrity.

### **Unfinished Business**

< Since SOLEC 98 no revisions have been made to this indicator - however, revisions will be made before the next version is released. Comments on this indicator are most welcome.

### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): humans

Related Issue(s): stewardship

SOLEC Grouping(s): stewardship

GLWQA Annex(es):

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s):

# Citizen/Community Place-Based Stewardship Activities

## Indicator ID: 3513

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### **Measure**

An enumeration and description of programs and projects that engage citizens in the stewardship of their landscapes /ecosystems and/or foster the ethic of stewardship; total number of identified programs, total number of participants, basin location.

### **Purpose**

Measures citizen stewardship action focused on places -- the landscapes in which they live.

### **Ecosystem Objective**

A Sustainable Great Lakes Ecosystem

### **Endpoint**

Continuing programs supporting a stewardship ethic and sense of responsibility for the landscapes within which people live. The building of a sense of place and the establishment of an identity for the local landscape including an understanding of the balance of interrelationships required to maintain the quality, health, and vitality of these landscapes over time.

A critical mass of local support for partnerships responsible for setting and maintaining levels of ecosystem health and integrity in places throughout the Great Lakes basin.

### **Features**

Identification of place-based landscape/ecosystem education programs. Identification of place-based landscape/ecosystem festivals. Identification of other place-based Landscape/Ecosystem programs which engage citizenry in stewardship activities and/or support a stewardship ethic and sense of place.

### **Illustration**

Graphs and charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

### **Limitations**

Some definition and interpretation will be required to set parameters for "programs and projects which engage citizens in the stewardship of their landscapes/ecosystems."

### **Interpretation**

Measures activities that indicate citizen/community engagement and support for stewardship.

### **Comments**

Community support for stewardship is required if governments, agencies, industry, and others are to adopt stewardship as a core value. In the case of some issues this support will be essential. For example, habitat protection will not be successfully addressed without the collaboration of local land use decision makers who have embraced the ethic of stewardship. The extent to which these local officials will actually respond to the need for habitat protection will be determined in part by the strength of the local constituency supporting stewardship as a community value.

### **Unfinished Business**

< Since SOLEC 98 no revisions have been made to this indicator - however, revisions will be made before the next version is released. Comments on this indicator are most welcome.

### **Relevancies**

Indicator Type: human activity

Environmental Compartment(s): humans

Related Issue(s): stewardship

SOLEC Grouping(s): stewardship

GLWQA Annex(es):

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s):



## Aesthetics

### Indicator ID: 7042

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#### **Measure**

Visible waste and refuse in communities around the basin.

#### **Purpose**

To directly measure the amount of waste and decay around human activities in the Great Lakes basin and to indirectly measure the degree to which human activities are conducted in an efficient and ordered fashion consistent with ecosystem harmony and integrity.

#### **Ecosystem Objective**

GLWQA Annex 2 requirement for aesthetics - cleanliness and freedom from evidence of waste.

#### **Endpoint**

Absence of obvious waste and decay around human activities and an obvious attention to cleanliness and respect for the environment.

#### **Features**

Aesthetics is an important aspect of society. It can relate to the management of other components of the ecosystem. Examples of poor aesthetics include waste oil and scum deposits in surface waterways, excessive trash along roadsides and on city streets, and run down and crumbling buildings within cities. The indicator is measured by a survey of waste and refuse that can be ascertained by a survey of communities in the basin. To determine the condition of aesthetics around the Great Lakes basin, surveys would need to be conducted to ascertain perspectives and opinions. This indicator is linked to other stewardship indicators, especially pollution prevention.

#### **Illustration**

#### **Limitations**

This indicator can be highly subjective although there is general agreement that obvious signs of waste and decay of private and public property are unaesthetic and signs of poor ecosystem management. The components of this indicator are not currently monitored since cleanliness and order can be highly subjective. Aesthetics should be kept in the context of waste or lack of maintenance and not become a matter or issue of taste and style.

#### **Interpretation**

This indicator represents a culture of maintenance and respect of the environment. A result approaching the endpoint indicates better care for the environment.

#### **Comments**

The level of order and cleanliness of a community, or other human activity (e.g., farm operation), can provide information on perspectives related to environmental health. Society has made no specific attempt to measure or comparatively evaluate this aspect.

#### **Unfinished Business**

- < Need to determine how often the surveys would be conducted (i.e., what are the temporal trends this indicator would measure?).
- < Need to determine how this indicator will be presented. For example, will a bar graph or a map be used?

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s): humans

Related Issue(s):

SOLEC Grouping(s): land use, societal

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s): 11: Degradation of aesthetics

## Economic Prosperity

### Indicator ID: 7043

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#### **Measure**

Unemployment rates within the Great Lakes basin.

#### **Purpose**

To directly measure unemployment rates within the Great Lakes basin and to indirectly measure the capacity of the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem.

#### **Ecosystem Objective**

Human economic prosperity is a goal of all governments. Full employment is a goal for all economies and humans are part of the ecosystem.

#### **Endpoint**

Achieving the lowest economically sustainable unemployment levels possible. Levels of unemployment under 5% in western societies are considered full employment.

#### **Features**

The indicator demonstrates the economic ability of humans to avoid abusive behaviour of the rest of the ecosystem. In a global context, wealthier nations (US and Canada, Europe) are more likely to also have better environmental management regimes because they can better afford them and can afford to avoid many of the highly exploitive choices with respect to the environment. Data on employment rates are collected regularly and frequently throughout the basin. The unemployment rate is a better indicator than gross domestic production per capita for this purpose since it focuses on human ability to meet their own needs through income provision and not necessarily through undesirable environmentally activities. For example, the oil spill from the Exxon Valdez increased gross domestic production, although it had a minimal effect on employment rates.

#### **Illustration**

The indicator will be best represented by a chart showing trends over years.

#### **Limitations**

The collection and presentation of the indicator information is not limited. It was noted in the World Commission on Environment and Development report "Our Common Future" that although economic well being is associated with higher levels of resource consumption and environmental degradation, higher levels of economic development afford the ability to better manage the ecosystem and can constrain unsustainable resource exploitation.

#### **Interpretation**

This indicator is useful in defining the extent to which society is meeting only human need and should be presented in the context of the other ecosystem indicators. Decreasing trends in unemployment may not correlate to improvements in the condition of the Great Lakes ecosystem. For example, higher employment levels may lead to greater spending, which may cause environmentally undesirable consequences, such as new sprawl development.

#### **Comments**

Since unemployment is determined from those actually seeking work, this is a good indicator of the degree to which society's pursuit of economic prosperity is being met.

Currently unemployment rates in the U.S. are at almost historic lows. Although distribution of income may not be ideal, there is a sense that the human component of the ecosystem is better off than it was prior to this period. Arguments for excessive ecosystem exploitation can be countered as not being necessary.

#### **Unfinished Business**

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s):

Related Issue(s):

SOLEC Grouping(s): societal

GLWQA Annex(es):

IJC Desired Outcome(s): 5: Economic viability

GLFC Objective(s):

Beneficial Use Impairment(s):

# Financial Resources Allocated to Great Lakes Programs

## Indicator ID: 8140

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### **Measure**

The total amount of dollars spent on an annual basis by federal and state/provincial agencies and non-governmental organizations in each of four areas: Great Lakes research, monitoring, restoration, and protection (including within nearshore lands).

### **Purpose**

To directly measure the amount of dollars spent annually on Great Lakes programs and to indirectly measure the responsiveness of Great Lakes programs by determining the adequacy of annual funding focused on research, monitoring, restoration, and protection of Great Lakes ecosystems by federal and state/provincial agencies and non-governmental organizations.

### **Ecosystem Objective**

Programs should be responsive to the degradation of shoreline communities and species. This indicator relates to the IJC Desired Outcome 6: Biological Community Integrity and Diversity.

### **Endpoint**

Fully funded research, monitoring, restoration, and protection programs for Great Lakes ecosystems.

### **Features**

This indicator will track the amount of dollars spent annually on Great Lakes research, monitoring, restoration, and protection programs. It will assess the number of projects, funding levels, and number of researchers across various factors, including type of funding source (e.g., government, non-government, private sector); levels of governments (e.g., local, State, Federal); basin wide; lakewide; regions of special interest; and types of research and locations. Data collection for this indicator will require a survey of major funding agencies, organizations and universities to identify key individuals and types of research or projects. The trends illustrated by this indicator can be used to determine which areas/issues require additional support, and where there are opportunities to shift funding.

### **Illustration**

Summary tables or graphs will be displayed for the entire basin and for each lake showing trends in the number of resources allocated for research, monitoring, restoration, and protection programs and projects.

### **Limitations**

Because it is often difficult to determine the spatial focus of various research projects (e.g., nearshore versus coastal wetlands), this indicator may double-count, or overlook, resources allocated to projects. A lack of historical data will make the assessment of funding trends over time difficult. To date, there has been no effort to collect this data. To initiate such an effort, and examine trends every 3 to 5 years, would require a substantial commitment. Obstacles to information collection may include freedom of information issues and difficulties in assessing private sector research efforts.

### **Interpretation**

This indicator could be used to compare investments in Biodiversity Investment Areas to overall program spending, or to other program areas such as restoration. A baseline will be established to determine what resources a program requires to be considered "fully funded." This information will serve as a baseline to determine if the endpoint for this indicator has been achieved.

### **Comments**

Received comments that this measure may be too dependent on political climate and not directly related to the benefits of the programs themselves. It is not clear how spending money is a meaningful or particularly sensitive societal response. This indicator should measure successful action. While it is agreed that this measure is not perfect, it can provide an initial estimate of the amount of attention given to various components of the Great Lakes ecosystem, such as nearshore terrestrial areas, over the long term. This indicator could be expanded to include factors such as the number of programs, policies, plans prepared, etc. as other indicators of agency interest.

This indicator may benefit from a ranking system that allows the return on investment to be assessed over time.

A change in funding levels may not be a reflection of the amount of attention the Great Lakes receive, but rather a reflection of budget issues.

### **Unfinished Business**

< Need to determine a quantitative reference value, such as a particular dollar amount based on programs needs assessed on an annual basis.

**Relevancies**

Indicator Type: human activity

Environmental Compartment(s): humans

Related Issue(s): stewardship

SOLEC Grouping(s): nearshore terrestrial, societal

GLWQA Annex(es):

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s):

# Global Warming: Number of Extreme Storms

## Indicator ID: 4519

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### **Measure**

For land areas adjacent to the Great Lakes, total number of “extreme storms”, per year during ice-free and ice-break-up periods on the Great Lakes.

### **Purpose**

To directly measure the number of “extreme storms” each year and to indirectly measure the impact of climate change on ecological components of coastal wetlands.

### **Ecosystem Objective**

GLWQA General Objective: “These waters should be free from materials and heat directly or indirectly entering the water as result of human activity that . . . produce conditions that are toxic or harmful to human, animal or aquatic life.” Change in atmospheric temperature will potentially affect the number of extreme storms in the Great Lakes region which will, in turn, affect coastal wetlands. Awareness of occurrence will encourage human response to reduce the stressor and minimize biological disruption. (IJC Desired Outcomes 6 and 9).

### **Endpoint**

An endpoint will need to be established, based on a literature search of historical data, if available, to determine the average number of extreme storms on the Great Lakes prior to a particular date.

### **Features**

Extreme storm events are a natural stressor than can occur anywhere in the basin and can potentially alter coastal wetlands and indicators of wetland health. There is natural variability in occurrences of extreme storm events, but the interpretation method tries to account for this, so the final score should have lower variability over time. Criteria to define an “extreme storm” (e.g., any storm below a central atmospheric pressure threshold or above a wind speed threshold) must be set.

This indicator may show similar trends to other indicators of climate change (ie. #4857 First Emergence of Water Lily Blossoms in Coastal Wetlands and #4858 Ice Duration on the Great Lakes). It is indirectly linked to any other indicator that track trends in wetland area/habitat change.

### **Illustration**

A graph with the total number of extreme storm events (not ice-bound) on the y axis and years on the x axis, beginning with the cut-off date for historical data. The graph will also indicate the historical median and extremes.

### **Limitations**

This indicator assumes that: 1) of all storms, “extreme storms” alter coastal wetlands the most (due to the combined effects of wind and waves; 2) storms throughout the basin represent storm effects on wetlands throughout the basin; and 3) historical data is available. It may take some time to collect data and to define historical reference levels.

### **Interpretation**

To interpret this indicator, data for “extreme storms” need to be gathered each year. From the recorded data of “extreme storms”, the pre-1980 median, maximum and minimum will be determined. The historic range will be divided into 3 equally occurring ranges: below average, average, and above average (i.e., the number of extreme storms/year exceeded 0-33.3%, 33.3% to 66.7%, 66.7% to 100% of the years of record before 1980). The indicator will score high if the annual numbers of extreme storms for the previous 10 years are within the maximum and minimum historical extremes and they are distributed fairly evenly among the 3 historical ranges. Low scores will be obtained if any annual Extreme storm numbers of the previous 10 years lie beyond the maximum or minimum extremes or they are becoming highly skewed away from a fairly even distribution among the 3 ranges.

Water levels, fetch and direction of storms may affect how storms influence individual wetlands.

### **Comments**

The concept of storm damage is very understandable to public.

An endpoint could be reached when the previous 10 years' values of numbers of extreme storms are evenly distributed within the pre-1980 historic range of number of extreme storms.

A technical report written by P.J. Lewis will provide a good starting point for historical data and assessment. The report was published by the Canadian Climate Centre, Technical Report #87-13, Severe Storms Over the Great Lakes: A Catalogue and Summary. 1957-1985. This report gives a fair amount of detail about each storm that had a least two reports of storm force winds (>48 knots) or greater.

### ***Unfinished Business***

< Need a definition of “extreme storms” - will it be based on wind speed, amount of precipitation, central atmospheric pressure of the storm, or the pressure gradient? Or some combination of two or more criteria.

### ***Relevancies***

Indicator Type: pressure

Environmental Compartment(s):

Related Issue(s): climate change

SOLEC Grouping(s): coastal wetlands, nearshore terrestrial, unbounded

GLWQA Annex(es):

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s):

# Global Warming: First Emergence of Water Lily Blossoms in Coastal Wetlands

## Indicator ID: 4857

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### **Measure**

The number of days after January 1 of first sighting of white on a water lily blossom, averaged over a representative set of coastal wetlands.

### **Purpose**

To directly measure change in first emergence dates of water lilies as an indicator of climate change affecting wetlands.

### **Ecosystem Objective**

GLWQA General Objective: "These waters should be free from materials and heat directly or indirectly entering the water as result of human activity that . . . produce conditions that are toxic or harmful to human, animal or aquatic life." Change in temperature potentially affects most biota. Awareness of occurrence will encourage human response to reduce the stressor towards minimizing biological disruption. (IJC Desired Outcomes 6 and 9).

### **Endpoint**

An endpoint will need to be established, based on a literature search of historical data, if available, to determine the average historical emergence date of water lilies, and to determine the earliest and latest recorded dates of first emergence. If no historical data are available, the endpoint will need to be established from data gathered from monitoring this indicator.

### **Features**

To monitor this indicator, a set of representative coastal wetland sites will be selected based on: 1) climate zones, 2) local observers and 3) associated historical data. The data will be collected annually. The data will have some variability due to natural climate variability and this will have to be considered when interpreting the data. Provided there are enough sites that meet the required criteria, collection and analysis of this indicator should be feasible.

This indicator may show similar trends to Ice Duration on the Great Lakes. It will be indirectly linked to indicators affected by climate change.

### **Illustration**

A graph will be displayed showing, annually, the number of days after January 1 (average of the sites) of the first sighting of white on a water lily blossom. The average historical emergence data, and the earliest and latest recorded dates, will be marked for reference and comparison.

### **Limitations**

A possible limitation may be locating sites that meet the needed criteria including on-site wetland observers and accessible water lilies. Monitoring would require frequent site visits for a period of time each year.

### **Interpretation**

To interpret this indicator, data for the white water lily or for a highly correlated reference crop need to be gathered. From the recorded date of first emergence, the historical earliest and latest dates will be determined. The historic range will be divided into 3 equally occurring date ranges: early, average, and late. Scores will be designed to be high if the annual averages for the previous 10 years are within high and low historical extremes AND they are distributed fairly evenly among the 3 historical ranges. Low scores will be obtained if annual averages lie beyond the high or low extremes OR they are becoming highly skewed away from a fairly even distribution among the 3 ranges.

### **Comments**

This indicator allows local people to become involved and aware of SOLEC. This indicator may have to be rethought if water lily data do not correlate well with historical data for a reference crop.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): biota

Related Issue(s): climate change

SOLEC Grouping(s): coastal wetlands, unbounded

GLWQA Annex(es):

IJC Desired Outcome(s):

GLFC Objective(s):

Beneficial Use Impairment(s):

# Global Warming: Maximum Ice Extent on the Great Lakes

## Indicator ID: 4858

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### **Measure**

Maximum percentage of Great Lakes area covered by ice each year.

### **Purpose**

To directly measure temperature and accompanying physical changes to each lake and to indirectly measure the impact of climate change on wetlands.

### **Ecosystem Objective**

GLWQA General Objective: "These waters should be free from materials and heat directly or indirectly entering the water as result of human activity that . . . produce conditions that are toxic or harmful to human, animal or aquatic life." Change in water temperature (potentially due to global warming) will affect ice extent on the Lakes and, in turn, affect coastal wetlands. Awareness of occurrence will encourage human response to reduce the stressor towards minimizing biological disruption. (IJC Desired Outcomes 6 and 9).

### **Endpoint**

An endpoint will need to be established, based on a literature search of historical data to determine the average number of days per year that ice historically (prior to 1980) formed on each lake.

### **Features**

Ice cover reflects temperature, wind, and heat stored in a lake, therefore, this is a good indicator of climate effects. This data is already collected annually for each lake by NOAA using satellite imagery. There is a natural variability in MAXIMUM ice extent accounted for in the interpretation.

This indicator may show similar trends to other indicators of climate change (ie. #4519 Number of Extreme Storms, #4857 First Emergence of Water Lily Blossoms in Coastal Wetlands, and #4861 Water Level Fluctuations). It is indirectly linked to any other indicator that track trends in wetland area/habitat change.

### **Illustration**

A graph displaying the maximum percentage of ice cover on the y axis and years on the x axis. The historical median and extremes will be indicated.

### **Limitations**

The data that have already been collected by NOAA are specific to each lake rather than coastal wetlands.

### **Interpretation**

Even though it is unclear if storms alter ice extent, storms can break up ice and alter their formation, therefore, information regarding storms and their severity is needed to properly interpret this indicator.

To interpret this indicator, data for maximum percentage ice cover need to be gathered each year. From the period of record for maximum percentage of ice cover, the pre-1980 high and low extremes will be determined. The historic range will be divided into 3 equally occurring ranges of maximum per cent ice cover: below average, average, and above average (i.e., maximum per cent ice cover exceeded 0 to 33.3%, 33.3.% to 66.7%, 66.7% to 100% of the pre-1980 years of record). The indicator will score high if the annual maximum percentage values for the previous 10 years are within the maximum and minimum historical extremes and they are distributed fairly evenly among the 3 historical ranges. Low scores will be obtained if any annual maximum percentage cover value lies beyond the high or low extremes or if the annual values are becoming highly skewed away from a fairly even distribution among the 3 ranges.

### **Comments**

This is a very understandable feature. Lake ice indicates coastal wetland ice and itself affects wetlands (e.g., winter storm severity).

The endpoint is reached when the previous 10 years' values of maximum per cent ice cover are distributed evenly within the pre-1980 historic range of maximum per cent ice cover.

### **Unfinished Business**

### **Relevancies**

Indicator Type: pressure  
Environmental Compartment(s):  
Related Issue(s): climate change



SOLEC Grouping(s): nearshore waters, coastal wetlands, unbounded  
GLWQA Annex(es):  
IJC Desired Outcome(s): 9: Physical environmental integrity  
GLFC Objective(s):  
Beneficial Use Impairment(s):

# Acid Rain

## Indicator ID: 9000

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### **Measure**

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).

### **Purpose**

To directly measure pH levels in precipitation and critical loadings of sulphate to the Great Lakes basin, and to indirectly measure the potential stress to the Great Lakes ecosystem due to acid rain, as well as to indirectly measure the efficacy of policies to reduce sulphur and nitrogen acidic compounds.

### **Ecosystem Objective**

The Canada/U.S. Accord on Air Quality pledges the two nations to reduce the emissions of acidifying compounds to the point where deposition containing these compounds does not adversely impact aquatic and terrestrial biotic systems.

### **Endpoint**

Levels of sulphate in wet deposition are not to exceed critical loads, defined by ecozone to be from 8 - 20 kg/ha/yr.

### **Features**

Measurements of sulphate deposition and pH are made by the US NDDN and Canadian CAPMoN networks along with provincial and state partners. These data are stored in databases on both sides of the border.

### **Illustration**

Data are routinely extracted from databases into annual maps of sulphate and pH deposition. These maps will be used to depict this indicator.

### **Limitations**

### **Interpretation**

This measure is not sufficient to fully understand the deposition problem and trends in pH concentration throughout the basin is another related indicator. Areas exceeding the sulphate critical load continue to be ecologically stressed due to high levels of acidity.

### **Comments**

Current projections show that this may not occur until after 2010.

The two specific measures tracked both provide indication of progress towards the goal of reducing acidifying substances.

Further progress in reduction of acidifying substances are required.

### **Unfinished Business**

< Need to determine what the target pH level is.

< Need to add more information on how often measurements of sulphate and pH are made, and the spatial trends (i.e., location of monitoring sites within the Great Lakes basin) described by this indicator.

### **Relevancies**

Indicator Type: pressure

Environmental Compartment(s): air

Related Issue(s): toxics

SOLEC Grouping(s): unbounded

GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances, 15: Airborne toxic substances, 17: Research and development

IJC Desired Outcome(s): 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s):

# Atmospheric Visibility: Prevention of Significant Deterioration

## Indicator ID: 9001

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### **Measure**

Percentage of daylight hours per year which have <10 km Visible Range (for relative humidity values < 80% and no observed weather codes from synoptic observations).

### **Purpose**

To directly measure the percentage of daylight hours with reduced visibility per year and to indirectly measure the efficacy of policies and technologies developed to improve visibility in the Great Lakes basin.

### **Ecosystem Objective**

### **Endpoint**

### **Features**

This indicator provides a measure of the visibility from human observers and from automated systems which relates to the progress made in limiting visibility reducing aerosols. Much progress has been made since 1951 in this regard and this progress should continue. Data exist back to 1951 in the U.S. and Canada and can form a trend statistic. Visibility is also an aesthetic problem, one which is most likely noticed by the public. This indicator is also an aesthetic indicator for land use. Further degradation of visibility in urban areas in the Great Lakes basin is to be avoided.

### **Illustration**

### **Limitations**

Recent changes in the observing protocols in Canada may lessen the number of stations capable of producing data on this indicator. However, automated observations which are tied to the prior data can be used as a surrogate. In the U.S., IMPROVE and NESCAUM observations stations can be used to infer this data.

### **Interpretation**

Visibility trends should show improvement over time. The SOLEC indicator (% hours < 10 km visibility) should decrease with time. If visibility is decreasing with time, major source types should be investigated. These include industrial production of sulphate aerosols, mobile sources of organic aerosols, nitrates and black carbon, and soil dust aerosols.

### **Comments**

The U.S. has designated atmospheric visibility as a protected value to be especially evaluated in its national parks. As part of the Clean Air Act, prevention of significant deterioration of visibility in Class I areas (largely national parks and forest reserves) is to be avoided. The PSD regulations require that visibility (measured in the number of kilometers distant one can see a black target of 0.02% contrast) not decrease.

Canada and the U.S. have agreed through the Air Quality Accord of 1990 that Canada will bring into effect sufficient controls to protect resources from transboundary impacts of visibility-reducing aerosols, in a manner similar to the US PSD regulations.

In Canada, regional stations, including Toronto, have relevant data for this statistic.

Typical measures of visibility are Meteorological Visible Range (km) observed by eyesight, aerosol light scattering coefficient (bscat, km<sup>-1</sup>) measured by nephelometers, or deciviews (a perceptive indicator related to bscat).

### **Unfinished Business**

- < Need to add an explanation of synoptic observations.
- < Need to provide an ecosystem objective.
- < Need to provide a quantifiable endpoint, such as the "ideal" percentage of daylight hours per year that have a <10 km visible range.
- < Need to provide more information on the spatial trends (i.e., location of monitoring sites within the Great Lakes basin) described by this indicator.
- < Need to determine how this indicator will be presented. For example, will a bar graph be used to illustrate trends in visibility over time?

### **Relevancies**

Indicator Type: state

Environmental Compartment(s): air

Related Issue(s):

SOLEC Grouping(s): unbounded  
GLWQA Annex(es): 11: Surveillance and monitoring, 15: Airborne toxic substances  
IJC Desired Outcome(s):  
GLFC Objective(s):  
Beneficial Use Impairment(s):

## Appendix 2 — Listing of All Indicators Entered into Database

The attached table contains a listing of over 800 indicators that have been entered into the database. The table includes:

- C the indicator name,
- C the indicator number or code,
- C what the indicator measures,
- C what agency/document the indicator originated from (any numbers in this column refer to the document numbers listed in Appendix 2), and
- C whether the indicator has been proposed for the SOLEC Indicator List (C.R. means Concept Retained in another indicator).

| Ind. code | Indicator name                  | Measure  | Program sponsor | SOLEC Indicator? |
|-----------|---------------------------------|--|-----------------|------------------|
| 1         | Lake herring                    | Rehabilitate to historical level of production   | GLFC - 1        | No               |
| 2         | Lake trout                      | Restore self-sustaining stocks to historical abundance   | GLFC - 1        | C.R.(93)         |
| 3         | Non-depleted native fishes      | Maintain stable, self-sustaining status  | GLFC - 1        | No               |
| 4         | Depleted native fishes          | Restore stable self-sustaining stocks  | GLFC - 1        | No               |
| 5         | Sea lamprey                     | Reduce population by 50% by 2000; 90% by 2010  | GLFC - 1        | No               |
| 6         | Aquatic Habitat                 | 1) Quality and area of aquatic habitat (e.g., shore, spawning shoals, tributaries, wetlands, etc.) and 2) population of sentinel fish species. For example, the measures for tributary quality could include the number of dams, number of miles of river channel that is impounded, number of miles of (formerly) high-gradient stream channel that is impounded, and the number of miles between the river mouth and the first dam. The number and location of fish passage facilities (up- and downstream) that could be used successfully by species or communities of concern (for example, lake sturgeon, or other anadromous fishes listed in FCGO) could also serve as measures. | GLFC - 1        | Yes              |
| 7         | Fish consumption advisories     | Reduce level in fish below FCA action levels   | GLFC - 1        | No               |
| 8         | Salmon and trout                | 1) Productivity, yield, or harvest using abundance (e.g., catch of each species in a given unit of sampling effort), or biomass metrics; and 2) population of stocked and naturally produced fish.   | GLFC - 5        | Yes              |
| 9         | Walleye and <i>Hexagenia</i>    | Abundance, biomass, or annual production of walleye and burrowing mayflies <i>Hexagenia</i> spp. populations in historical, warm-coolwater, mesotrophic habitats of the Great Lakes. Presence or absence of a <i>Hexagenia</i> mating flight (emergence) in late June- July in areas of historical abundance.  |                 | Yes              |
| 10        | Yellow perch                    | Maintain as top omnivore; 0.5Mkg/y   | GLFC - 5        | No               |
| 11        | Northern pike                   | Maintain as prominent predator   | GLFC - 5        | No               |
| 12        | Muskellunge                     | Manage to support trophy fishery   | GLFC - 5        | No               |
| 13        | Lake Whitefishes                | Quantify using either numbers or biomass.  | GLFC - 5        | No               |
| 14        | Lake whitefish and lake herring | Maintain self-sustaining stocks yielding 3.8Mkg/y  | GLFC - 5        | No               |
| 15        | Bass and sunfish                | Maintain at recreationally attractive levels   | GLFC - 5        | No               |
| 16        | Lake sturgeon                   | Rehabilitate populations; delist as T or E spp.  | GLFC - 5        | No               |
| 17        | Preyfish Populations            | Abundance and diversity, as well as age and size distribution, of preyfish species (i.e., deepwater ciscoes, sculpins, lake herring, rainbow smelt, and alewives) in each lake.  | GLFC - 5        | Yes              |
| 18        | Sea lamprey                     | Number of spawning run adult sea lampreys; wounding rates on large salmonids.  | GLFC - 5        | Yes              |
| 19        | Native species diversity        | Total number of different species in a collection (see features). Comparison of historical with present conditions.  | GLFC - 5        | No               |
| 20        | Genetic diversity               | Heterozygosity (allozyme, allelic); nuclear or mitochondrial DNA polymorphisms; population pairwise genetic distance; nucleon diversity/gene diversity; genetic variability; genetic uniqueness.   | GLFC - 5        | No               |
| 21        | Habitat                         | No net loss; rehabilitate degraded habitats  | GLFC - 5        | No               |
| 22        | Habitat                         | Reduce or eliminate contaminants   | GLFC - 5        | No               |

| Ind. code | Indicator name                        | Measure  | Program sponsor   | SOLEC Indicator? |
|-----------|---------------------------------------|--|-------------------|------------------|
| 23        | Salmon and trout                      | Establish diverse community yielding 6-15Mlbs/y  | GLFC - 2          | No               |
| 24        | Planktivores (preyfish)               | Match to primary production and predator demand  | GLFC - 2          | No               |
| 25        | Inshore fish                          | Maintain self-sustaining stocks; yield >2-4Mlbs/y  | GLFC - 2          | No               |
| 26        | Benthivore (fish)                     | Maintain self-sustaining stocks  | GLFC - 2          | No               |
| 27        | Benthivore (lake whitefish)           | Maintain self-sustaining stocks; yield 4-6M lbs/y  | GLFC - 2          | No               |
| 28        | Sea lamprey                           | Reduce to achieve other fish community objective   | GLFC - 2          | No               |
| 29        | Other species (fish)                  | Protect diverse native fish community  |                   | No               |
| 30        | Habitat                               | No net loss; restore riverine spawning habitat   | GLFC - 2          | No               |
| 31        | habitat                               | Reduce or eliminate contaminants   | GLFC - 2          | No               |
| 32        | Lake trout                            | Restore self-sustaining populations; 0.5-1 M adult   | GLFC - 3          | No               |
| 33        | Warmwater fish                        | Maintain current complex; yield 1 kg/ha/y  | GLFC - 3          | No               |
| 34        | Preyfish                              | Maintain major species; mean biomass 110 kg/ha/y   | GLFC - 3          | C.R.(17)         |
| 35        | Salmon, trout, and whitefishes        | Maintain diverse complex; yield 2.5 kg/ha/y  | GLFC - 3          | No               |
| 36        | Sea lamprey                           | Limit lake trout mortality to <90,000 fish/y   | GLFC - 3          | No               |
| 37        | Lake trout                            | Health indicator for coldwater fish community  | IJC               | No               |
| 38        | Walleye                               | Health for mesotrophic ecosystem; yield .3 kg/ha/y   | IJC               | No               |
| 39        | Hexagenia (burrowing mayfly)          | Health indicator for mesotrophic ecosystem   | IJC - 30          | No               |
| 40        | Exotic species                        | Effects of   | SOLEC             | No               |
| 41        | Native species and habitats           | Status of  | SOLEC             | No               |
| 42        | Persistent toxics                     | Levels in water and sediment   | SOLEC             | No               |
| 43        | Persistent toxics                     | Levels in fish and wildlife  | SOLEC             | No               |
| 44        | Nutrient loading                      | DO levels in bottom waters   | SOLEC             | No               |
| 45        | Nutrient loading                      | Water clarity and algal blooms   | SOLEC - 28        | No               |
| 47        | Nutrient loading                      | Maintain mesotrophic conditions (10-20 ug P/L)   | GLFC - 4          | No               |
| 48        | Nutrient loading                      | Manage loadings to yield 50-60 M lbs good fish/y   | GLFC - 4          | C.R.(111)        |
| 49        | Habitat                               | Manage nearshore habitat for quality fisheries   | GLFC - 4          | No               |
| 50        | Riverine habitat                      | Protect spawning habitat of anadromous fish  | GLFC - 4          | No               |
| 51        | Western basin ecosystem               | Manage for warm and coolwater fishes   | GLFC - 4          | No               |
| 52        | Central basin ecosystem               | Manage for warm, cool, and coldwater fishes  | GLFC - 4          | No               |
| 53        | Eastern basin ecosystem               | Emphasize management for coldwater fishes  | GLFC - 4          | No               |
| 54        | Contaminants                          | Reduce levels to no effect on fish production  | GLFC - 4          | C.R.(112)        |
| 55        | Habitat                               | Adequate habitat to support fish community goals   | GLFC - 4          | No               |
| 56        | Genetic diversity                     | Conserve locally adapted strains   | GLFC - 4          | No               |
| 57        | Rare, Threatened & Endangered species | Manage to preserve and protect   | GLFC - 4          | No               |
| 58        | Preyfish                              | Manage as prey, baitfish, and human food (smelt)   | GLFC - 4          | No               |
| 59        | Food web                              | Manage to meet fish community objectives   | GLFC - 4          | No               |
| 60        | Diaporeia and Hexagenia               | Manage as prey and indicators of habitat quality   | GLFC - 4          | No               |
| 61        | Biomass/production size spectrum      | Ecosystem structure  | Ontario LaMP - 11 | No               |
| 62        | Yield of piscivores                   | Commercial and sport catch   | Ontario LaMP - 11 | No               |
| 63        | Piscivore/prey biomass                | Ecosystem health   | Ontario LaMP - 11 | No               |
| 64        | Fraction of yield as native fish      | Ratio of native to exotic species of fish.   | Ontario LaMP - 11 | C.R.(8)          |
| 65        | Zooplankton size distribution         | Ecosystem structure; predation, and productivity   | Ontario LaMP - 11 | No               |
| 66        | Total P levels <= 10 mg/L             | Baseline productivity  | Ontario LaMP - 11 | No               |
| 67        | Small native bivalve presence         | Ecosystem health   |                   | No               |
| 68        | Native Unionid Mussels                | Distribution and abundance, reported as number of individuals per unit of sampling effort; soft tissue weight; and reproductive output of the Native Unionid mussel.   | USEPA - 47        | Yes              |
| 69        | Submersed aquatic vegetation          | Condition of physical habitat; nutrient loading  | USEPA - 47        | No               |
| 70        | Municipal discharges: BOD, TSS, Pf    | Water quality  | EC - 39           | No               |
| 71        | Petroleum industry liquid discharges  | Water quality  | EC - 39           | No               |
| 72        | Fish Entrainment                      | 1) Water withdrawal rates in m <sup>3</sup> /sec (gal/min) at once-through cooling at steam-electric and pumped-storage power plants in the Great Lakes; and 2) calculated total annual mortalities (losses) of sentinel species at each plant in each lake. | EC - 39           | Yes              |
| 73        | Fishability                           | Contaminant levels in fish; fish advisories  | IJC - 35          | No               |

| Ind. code | Indicator name  | Measure  | Program sponsor     | SOLEC Indicator? |
|-----------|---|--|---------------------|------------------|
| 74        | Biological community integrity and diversity                | Multiple; biota and habitat  | IJC - 35            | No               |
| 75        | Virtual elimination persistent toxics                       | Multiple; mixed  | IJC - 35            | C.R.(112)        |
| 76        | Phosphorus  | Multiple; mixed  | IJC - 35            | C.R.(111)        |
| 77        | Physical environment integrity                              | Multiple; mixed  | IJC - 35            | No               |
| 78        | Loss of native species                                      | Number of species lost   | SOLEC - 22          | No               |
| 79        | Ecosystem imbalance   | Lake trout dichotomous key   | IJC - 35            | No               |
| 80        | Reproductive impairment                                     | EMS; female parent contaminant body burden   | IJC - 35            | No               |
| 81        | Nutrient stress   | P level, DO level; Chlorophyll a   | IJC - 35            | C.R.(111)        |
| 82        | Contaminant stresses  | loadings, residues, body burdens   | IJC - 35            | No               |
| 83        | Lake trout  | lake trout dichotomous key   | IJC - 29            | No               |
| 84        | Mesotrophic biological surrogates                           | Walleye and Hexagenia  | IJC - 31            | No               |
| 85        | Fish habitat--in 43 AOCs                                    | Habitat supports fish community objectives   | GLFC/EC/USE PA - 41 | No               |
| 86        | Fish community  | Site specific; 43 sites  | GLFC/EC/USE PA - 41 | No               |
| 87        | Habitat   | Areas of aquatic vegetation and loose rock substrate   | Ontario LaMP - 12   | No               |
| 88        | White sucker  | Basin-wide toxics  | IJC - 36            | No               |
| 89        | Lake trout  | Oligotrophic habitats  | IJC - 36            | No               |
| 90        | Walleye, Hexagenia  | Basin-wide mesotrophic habitats  | IJC - 36            | No               |
| 91        | Brown bullhead, Hexagenia, benthic community                | Toxics in AOCs   | IJC - 36            | No               |
| 92        | Walleye and Hexagenia                                       | Walleye, 0.3kg/ha/y; Hexagenia, 200/m2/y/3y  | IJC - 30            | No               |
| 93        | Lake Trout and Scud ( <i>Diaporeia hoyi</i> )               | Abundance, yield, or biomass, and self-sustainability of lake trout and <i>D. hoyi</i> in coldwater, oligotrophic habitats of the Great Lakes. | IJC - 30            | Yes              |
| 94        | Fish community structure and function                       | Annual harvest of trout and salmon (M lbs)   | Michigan LaMP - 9   | No               |
| 95        | Fish community structure and function                       | Annual harvest of planktivores (M lbs)   | Michigan LaMP - 9   | No               |
| 96        | Fish community structure and function                       | Annual harvest of inshore fishes (M lbs)   | Michigan LaMP - 9   | No               |
| 97        | Fish community structure and function                       | Annual harvest of benthivore fishes (M lbs)  | Michigan LaMP - 9   | No               |
| 98        | Fish community structure and function                       | Annual harvest of other native fishes (M lbs)  | Michigan LaMP - 9   | No               |
| 99        | Reproduction and self-sustainability                        | Lake trout   | Michigan LaMP - 9   | No               |
| 100       | Fish habitat and spawning grounds                           | lake trout spawning habitat; coastal wetland sp. H   | Michigan LaMP - 9   | No               |
| 101       | Deformities, Erosion, Lesions and Tumours in Nearshore Fish | Frequency of tumors and other related anomalies in nearshore fish.   | Michigan LaMP - 9   | Yes              |
| 102       | Tainting of fish flavor                                     | Annual number of complaints for sport fish   | Michigan LaMP - 9   | No               |
| 103       | Exotics   | lamprey wounding rates; presence of other species  | Michigan LaMP - 9   | No               |
| 104       | Benthos Diversity and Abundance                             | Species diversity and abundance in the aquatic oligochaete community.  | Michigan LaMP - 9   | Yes              |
| 105       | Tributaries   | Macroinvertebrate community; IBI, MBI, etc.  | Michigan LaMP - 9   | No               |
| 106       | Dredging activities   | Contaminant level in sediments   | Michigan LaMP - 9   | No               |
| 107       | Contaminant levels to protect aquatic life                  | Concentration of toxics in water column  | Michigan LaMP - 9   | No               |
| 108       | Eutrophication  | Total P and ammonia in water   | Michigan LaMP - 9   | No               |
| 109       | Phytoplankton Populations                                   | Species and size, fractionated by Carbon-14 uptake, of phytoplankton populations.  |                     | Candidate        |
| 110       | Zero discharge and emission of 9 toxic contaminants         |  | Superior LaMP       | C.R.(112)        |
| 111       | Phosphorus Concentrations and Loadings                      | Total phosphorus levels (ug/L).  |                     | Yes              |

| Ind. code | Indicator name  | Measure  | Program sponsor                       | SOLEC Indicator?         |
|-----------|---|--|---------------------------------------|--------------------------|
| 112       | Trends in Contaminant Concentrations & Loadings of Priority Chemicals in Abiotic Media: Water, Air, Soil, and Sediments | This indicator will use the contaminant concentrations and computational methodology to compute the loadings, trends, and exchanges of priority toxic chemicals between air, water, and sediment. Fugacity based approaches of intermedia transport will also be included as part of the indicator.  |                                       | C.R.(117, 118, 119, 120) |
| 113       | Contaminants in Recreational Fish   | Concentration of PBT chemicals in the catch-weighted average, edible tissue of recreational fish.  | New                                   | Yes                      |
| 114       | Contaminants In Young-of-the Year Spottail Shiners  | Concentration of PBT chemicals in young-of-the-year spottail shiners.  | New                                   | Yes                      |
| 115       | Contaminants in Colonial Nesting waterbirds   | 1) Annual concentrations of DDT complex, PCBs/PCDFs/PCDDs and other organic contaminants and Hg and other metals in Herring Gull eggs from 15 sites from throughout the Great Lakes (U.S. and Canada). 2) Periodic measurement of biological features of gulls and other colonial waterbirds known to be directly or indirectly impacted by contaminants and other stressors. These include (but are not limited to): clutch size, eggshell thickness, hatching and fledging success, size and trends in breeding population, various physiological biomarkers including vitamin A, immune and thyroid function, stress hormone levels, liver enzyme induction, PAH levels in bile and porphyrins and genetic and chromosomal abnormalities. | New                                   | Yes                      |
| 116       | Zooplankton Populations as Indicators of Ecosystem Health   | 1) Community Composition; 2) Mean Individual Size; and 3) Biomass and Production.  |                                       | Candidate                |
| 117       | Atmospheric Deposition of Toxic Chemicals   | Annual average loadings of IJC priority toxic chemicals from the atmosphere to the Great Lakes, based on measured atmospheric concentrations of the chemicals, as well as wet and dry deposition rates.  |                                       | Candidate                |
| 118       | Toxic Chemical Concentrations in Offshore Waters  | The concentration of IJC priority toxic chemicals in the offshore waters of the Great Lakes.   |                                       | Candidate                |
| 119       | Concentrations of Contaminants in Sediment Cores  | The concentrations of IJC priority toxic chemicals in sediment cores at selected sites within the Great Lakes at ten year intervals.   |                                       | Candidate                |
| 120       | Contaminant Exchanges Between Media: Air to Water and Water to Sediment   | Estimates of air to water and water to sediment loadings of IJC priority toxic chemicals using fugacity based approaches of intermedia transport.  |                                       | Candidate                |
| 1000      | Biomass/Production Size Spectrum  |  | USEPA - 46                            | No                       |
| 1001      | Excess Nutrients  | Total Phosphorus and Nitrogen Levels   | USEPA - 46, Ontario LaMP - 11         | No                       |
| 1002      | Zooplankton Size Distribution   | Mean Zooplankton Length  | Ontario LaMP - 11                     | No                       |
| 1003      | Production or Yield of Piscivores   |  | Ontario LaMP - 11                     | No                       |
| 1004      | Piscivore/Prey Fish Biomass Ratio   |  | Ontario LaMP - 11                     | No                       |
| 1005      | Fraction Yield as Native Fish   | Naturally Producing Fish to Salmonine Populations  | Ontario LaMP - 11                     | No                       |
| 1006      | Contaminant Body Burdens  | DDT, PCB, dieldrin concentrations in lake trout  | Ontario LaMP                          | No                       |
| 1007      | Burrowing Mayfly Nymphs   | Easily quantified using either numbers or biomass  | GLFC - 1, Ontario LaMP - 12, IJC - 31 | No                       |
| 1008      | Trends in Abundance of Key Species  | Index Target Abundances (e.g. lake trout, diporeia)  | GLFC - 7                              | No                       |
| 1009      | Lake Herring Stocks   | Annual Yields  | GLFC - 1                              | No                       |
| 1010      | Salmonine Stocks  | Annual Yields of Salmon and Trout  | GLFC - 1                              | No                       |
| 1011      | Planktivore (prey) Species Biomass  |  | GLFC - 2                              | No                       |
| 1012      | Rarity of Species and Communities   |  | SOLEC - 19                            | No                       |
| 1013      | Non-Native/Exotic Species   |  | USEPA - 46                            | No                       |
| 1014      | Species Richness  | Total number of different species in a collection  | USEPA - 46                            | No                       |
| 1015      | Human Population Size   | Population Size from census data   | USEPA - 46                            | No                       |
| 1016      | Tern Populations  | Common and Caspian Terns   | Ontario LaMP - 12                     | No                       |
| 1017      | Herring Gull  |  | Ontario LaMP - 12, IJC - 31           | No                       |



| Ind. code | Indicator name                                 | Measure  | Program sponsor            | SOLEC Indicator? |
|-----------|--|--|----------------------------|------------------|
| 1018      | Bald Eagle/Osprey Populations                  |  | Ontario LaMP - 12          | No               |
| 1019      | Double-Crested Cormorant                       |  | Ontario LaMP - 12          | No               |
| 1020      | Contaminant Concentrations in Water            | PCB, DDE, dieldrin, HCB, BaP                   | SOLEC - 16                 | No               |
| 1021      | Induction of Mixed Function Oxidase Enzymes    | P450 1A1                                       | SOLEC - 18                 | No               |
| 1022      | Inhibition of Amino Levulinic Acid Dehydratase |  | SOLEC - 18                 | No               |
| 1023      | Hepatic Porphyria                              |  | SOLEC - 18                 | No               |
| 1024      | Hepatic Vitamin A (Retinol)                    |  | SOLEC - 18                 | No               |
| 1025      | Thyroid Related Abnormalities                  |  | SOLEC - 18                 | No               |
| 1026      | Tumor Incidence                                |  | SOLEC - 18                 | No               |
| 1027      | Fin Ray Asymmetry                              |  | SOLEC - 18                 | No               |
| 1028      | Congenital Malformations                       |  | SOLEC - 18                 | No               |
| 1029      | Disease Incidence                              |  | SOLEC - 18                 | No               |
| 1030      | Parasite Incidence                             |  | SOLEC - 18                 | No               |
| 1031      | Walleye Abundance                              |  | Ontario LaMP - 12          | No               |
| 1032      | Exceedance of Water Quality Guidelines         | Bacterial Contamination                        | EC - 38                    | No               |
| 1033      | Total discharge via leakages                   | kg of pollutants and metals                    | EC - 38                    | No               |
| 1034      | Contaminants discharged by STP in kg/day       |  | EC - 38                    | No               |
| 1035      | Industrial effluent discharged per day         |  | EC - 38                    | No               |
| 1036      | Zinc Loadings                                  | Total kg per year                              | EC - 38                    | No               |
| 1037      | Iron Loadings                                  |  | EC - 38                    | No               |
| 1038      | Phenols Loadings                               | Total kg per year                              | EC - 38                    | No               |
| 1039      | TSS Discharge                                  | Total kg/day                                   | EC - 38                    | No               |
| 1040      | Cyanide Loadings                               | Total kg/day                                   | EC - 38                    | No               |
| 1041      | BOD Loadings                                   | STP effluent concentrations (mg/L)             | EC - 38                    | No               |
| 1042      | TSP Concentrations                             | mg/L   | EC - 38                    | No               |
| 1043      | Fecal coliform concentration                   | MF count/100 ml                                | EC - 38                    | No               |
| 1044      | Chlorine Concentrations                        | mg/L   | EC - 38                    | No               |
| 1045      | Concentration of cadmium                       | mg/L   | EC - 38                    | No               |
| 1046      | Concentration of chromium                      | mg/L   | EC - 38                    | No               |
| 1047      | Concentration of lead                          | mg/L   | EC - 38                    | No               |
| 1048      | Concentration of aluminum                      | mg/L   | EC - 38                    | No               |
| 1049      | Concentration of Mirex                         | ng/L   | EC - 38                    | No               |
| 1050      | Concentration of copper                        | mg/L   | EC - 38                    | No               |
| 1051      | Growth rate of individuals                     |  | IJC - 33                   | No               |
| 1052      | Carcinogenesis                                 |  | IJC - 33                   | No               |
| 1053      | Teratogenesis and Congenital Defects           |  | IJC - 33                   | No               |
| 1054      | Susceptibility to Disease                      |  | IJC - 33                   | No               |
| 1055      | Behavioural Effects                            |  | IJC - 33                   | No               |
| 1056      | Morphological Changes                          | Algal cells, etc.                              | IJC - 33                   | No               |
| 1057      | Feminization                                   |  | IJC - 33                   | No               |
| 1058      | Natality and Mortality                         |  | IJC - 33                   | No               |
| 1059      | Population Age Structure                       |  | IJC - 33                   | No               |
| 1060      | Number of Breeding Pairs                       |  | IJC - 33                   | No               |
| 1061      | Geographical Range of Population               |  | IJC - 33                   | No               |
| 1062      | Decomposition                                  |  | IJC - 33                   | No               |
| 1063      | Phosphorus Loadings                            | Chorophyte - Cladophora                        | IJC - 33                   | No               |
| 1064      | Fugacity                                       | Partial pressure/escaping tendency of chemical | University of Toronto - 60 | No               |
| 1065      | Water Transparency                             |  | OMNR/NYSDE C - 50          | No               |
| 1066      | Ratio of Specialist to Generalist Organisms    |  | IJC - 31                   | No               |
| 1067      | Tainting of Fish Flavour                       |  | GLFC                       | No               |

| Ind. code | Indicator name  | Measure   | Program sponsor    | SOLEC Indicator? |
|-----------|---|---|--------------------|------------------|
| 1068      | Ammonia   | Degradation of Phytoplankton and Zooplankton  | Michigan LaMP - 9  | No               |
| 1070      | TKN   | Degradation of Phytoplankton and Zooplankton  | Michigan LaMP - 9  | No               |
| 1071      | Total Phosphorus  | Degradation of Phytoplankton and Zooplankton  | Michigan LaMP - 9  | No               |
| 1072      | Total Dissolved Si  | Degradation of Phytoplankton and Zooplankton  | Michigan LaMP - 9  | No               |
| 1073      | Total Organic Carbon  | Degradation of Phytoplankton and Zooplankton  | Michigan LaMP - 9  | No               |
| 1074      | Total Suspended Solids  | Degradation of Phytoplankton and Zooplankton  | Michigan LaMP - 9  | No               |
| 1075      | Chlorides   | Degradation of Phytoplankton and Zooplankton  | Michigan LaMP - 9  | No               |
| 1076      | Dissolved Oxygen  | Degradation of Phytoplankton and Zooplankton  | Michigan LaMP - 9  | No               |
| 1077      | Temperatures  | Degradation of Phytoplankton and Zooplankton  | Michigan LaMP - 9  | No               |
| 1078      | Secchi Depth  | Degradation of Phytoplankton and Zooplankton  | Michigan LaMP - 9  | No               |
| 3500      | Reinvestment in Natural Capital                               |   | Superior LaMP - 14 | No               |
| 3501      | Citizen Involvement in Decision Making                        |   | Superior LaMP - 14 | No               |
| 3502      | Per Capita Membership in Community Organizations              |   | Superior LaMP - 14 | No               |
| 3503      | Energy Consumption  |   | Superior LaMP - 14 | No               |
| 3504      | Waste Stream Loadings   |   | Superior LaMP - 14 | No               |
| 3505      | Political Pressure - Protect/Remediate Environment            |   | Superior LaMP - 14 | No               |
| 3506      | Diversity of Cultures   |   | Superior LaMP - 14 | No               |
| 3507      | Basin-Wide Sense of Identity                                  |   | Superior LaMP - 14 | No               |
| 3508      | General Participation in Environmental Programs               |   | Superior LaMP - 14 | No               |
| 3509      | Capacities of Sustainable Landscape Partnerships              | Number of partnerships; basin location and geographic coverage; budgets, FTE staff; identification of major projects and initiatives  |                    | Candidate        |
| 3510      | Organizational Richness of Sustainable Landscape Partnerships | The diversity of the members participating in partnerships measured on two axes: Horizontal Integration -- the diversity of local partners; and Vertical Integration -- the direct participation of federal and state/provincial actors in local partnership initiatives. |                    | Candidate        |
| 3511      | Integration of Ecosystem Management across Landscapes         | Simple reporting of the adoption of ecosystem management as a guiding principle in place-based resource management programs by states/provinces and regional agencies and governments and budget allocations in support of ecosystem management programs and projects.    |                    | Candidate        |
| 3512      | Integration of Sustainability Principles across Landscapes    | Simple reporting of the adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments and budget allocations in support of sustainability initiatives and projects.  |                    | Candidate        |
| 3513      | Citizen/Community Place-Based Stewardship Activities          | An enumeration and description of programs and projects that engage citizens in the stewardship of their landscapes/ecosystems and/or foster the ethic of stewardship; total number of identified programs, total number of participants, basin location.                 |                    | Candidate        |
| 4078      | Drinking Water Quality  | Chemical concentration in finished drinking water   | Superior LaMP - 14 | C.R.(4175)       |
| 4079      | Drinking Water Quality  | Microbial contaminants in finished drinking water   | Superior LaMP - 14 | C.R.(4175)       |

| Ind. code | Indicator name   | Measure  | Program sponsor    | SOLEC Indicator? |
|-----------|--|--|--------------------|------------------|
| 4081      | Fecal Pollution Levels of Nearshore Recreational Waters    | 1) Counts of fecal coliforms (FC) and/or <i>E.coli</i> in recreational waters measured as number of organisms per volume of water (e.g., FC/ml); and 2) frequency of beach closings at specific locations. | Superior LaMP - 14 | Yes              |
| 4082      | Contaminants in Air  | Concentration of chemicals and particulates in ambient air   | Superior LaMP - 14 | C.R.(4176)       |
| 4083      | Chemical Contaminants in Fish Tissue                       | Concentration of PBT chemicals targeted by the GLWQA in edible fish tissue   | Superior LaMP - 14 | Yes              |
| 4084      | Chemical Contaminants in Human Tissue 1                    | Breast milk: Concentration of PBT chemicals  | Health Canada - 56 | C.R.(4177)       |
| 4085      | Chemical Contaminants in Human Tissue 2                    | Blood lead concentrations in children  | Health Canada - 56 | No               |
| 4086      | Chemical Contaminants in Human Tissue 3                    | Geographic comparisons of chemical contaminants in human tissue (blood, milk and hair)   | Health Canada - 56 | C.R.(4177)       |
| 4087      | Chemical Contaminants in Human Tissue 4                    | Umbilical cord blood: Concentration of PBT chemicals   | USEPA              | C.R.(4177)       |
| 4088      | Chemical Contaminant Intake From Air, Water, Soil and Food | Estimated total daily intake of PBT chemicals targeted by the GLWQA from air, water, soil, and food sources.   | Health Canada - 56 | Yes              |
| 4089      | Radionuclides 1  | Concentration of Cs-137 and Sr-90 in cow's milk  | Superior LaMP - 14 | C.R.(4178)       |
| 4090      | Radionuclides 2  | Concentration of H-3 (tritium) and C-14 in surface water, drinking water, and air  | Superior LaMP - 14 | C.R.(4178)       |
| 4091      | Air Quality and Cardiorespiratory Health 1                 | Relationship between respiratory admissions to hospitals and ozone and sulphate levels.  | Health Canada - 56 | C.R.(4176)       |
| 4092      | Air Quality and Cardiorespiratory Health 2                 | Cardiorespiratory hospital admissions and sulfate levels   | Health Canada - 56 | C.R.(4176)       |
| 4093      | Cancer Risk and Chlorination Byproducts in Drinking Water  | Correlation of THM levels in drinking water with cancer incidence  | Health Canada - 56 | C.R.(4175)       |
| 4094      | Cancer Incidence Rates                                     | Geographic distribution of cancer incidence in the Great Lakes region  | Health Canada - 56 | C.R.(4179)       |
| 4095      | Birth Defects Incidence Rates                              | Geographic distribution of birth defect rates in the Great Lakes region  | Health Canada - 56 | C.R.(4179)       |
| 4096      | Social Indicators  | Public knowledge, attitudes, and behaviors regarding use of Great Lakes resources  | Health Canada - 56 | No               |
| 4102      | Contaminants in Fish                                       | Aldrin/dieldrin in Indicator Species   | Superior LaMP - 14 | No               |
| 4103      | Contaminants in Fish                                       | Benzo(a)pyrene in Indicator Species  | Superior LaMP - 14 | No               |
| 4104      | Contaminants in Fish                                       | Chlordane in Indicator Species   | Superior LaMP - 14 | No               |
| 4105      | Contaminants in Fish                                       | DDT and metabolites in Indicator Species   | Superior LaMP - 14 | No               |
| 4106      | Contaminants in Fish                                       | Hexachlorobenzene in Indicator Species   | Superior LaMP - 14 | No               |
| 4107      | Contaminants in Fish                                       | Alkyl-lead in Indicator Species  | Superior LaMP - 14 | No               |
| 4108      | Contaminants in Fish                                       | Mercury and compounds in Indicator Species   | Superior LaMP - 14 | C.R.(4083)       |
| 4109      | Contaminants in Fish                                       | Mirex in Indicator Species   | Superior LaMP - 14 | C.R.(4083)       |
| 4110      | Contaminants in Fish                                       | Octachlorostyrene in Indicator Species   | Superior LaMP - 14 | No               |
| 4111      | Contaminants in Fish                                       | PCBs in Indicator Species  | Superior LaMP - 14 | C.R.(4083)       |
| 4112      | Contaminants in Fish                                       | Dioxins and Furans in Indicator Species  | Superior LaMP - 14 | C.R.(4083)       |
| 4113      | Contaminants in Fish                                       | Toxaphene in Indicator Species   | Superior LaMP - 14 | C.R.(4083)       |
| 4114      | Contaminants in Drinking Water                             | Lead in raw and treated water  | Superior LaMP - 14 | C.R.(4078)       |
| 4115      | Contaminants in Drinking Water                             | Mercury in raw and treated water   | Superior LaMP - 14 | C.R.(4078)       |
| 4116      | Contaminants in Drinking Water                             | Benzene in raw and treated water   | Superior LaMP - 14 | No               |

| Ind. code | Indicator name                          | Measure  | Program sponsor    | SOLEC Indicator? |
|-----------|---|--|--------------------|------------------|
| 4117      | Contaminants in Drinking Water          | Chlordane in raw and treated water                 | Superior LaMP - 14 | No               |
| 4118      | Contaminants in Drinking Water          | Dibromochloropropane in raw and treated water      | Superior LaMP - 14 | No               |
| 4119      | Contaminants in Drinking Water          | Ethylenedibromide in raw and treated water         | Superior LaMP - 14 | No               |
| 4120      | Contaminants in Drinking Water          | Toxaphene in raw and treated water                 | Superior LaMP - 14 | No               |
| 4121      | Contaminants in Drinking Water          | Hexachlorobenzene in raw and treated water         | Superior LaMP - 14 | No               |
| 4122      | Contaminants in Drinking Water          | Benzo(a)pyrene in raw and treated water            | Superior LaMP - 14 | No               |
| 4123      | Contaminants in Drinking Water          | PCBs in raw and treated water                      | Superior LaMP - 14 | No               |
| 4124      | Contaminants in Drinking Water          | 2,3,7,8-TCDD in raw and treated water              | Superior LaMP - 14 | No               |
| 4125      | Contaminants in Drinking Water          | Coliform in raw and treated water                  | Superior LaMP - 14 | C.R.(4079)       |
| 4126      | Contaminants in Drinking Water          | Fecal coliform in raw and treated water            | Superior LaMP - 14 | C.R.(4079)       |
| 4127      | Contaminants in Air                     | Ozone concentrations in air                        | Superior LaMP - 14 | C.R.(4082)       |
| 4129      | Contaminants in Air                     | Particulate matter concentrations in air           | Superior LaMP - 14 | C.R.(4082)       |
| 4130      | Contaminants in Air                     | Carbon monoxide concentrations in air              | Superior LaMP - 14 | C.R.(4082)       |
| 4131      | Contaminants in Air                     | Volatile Organic Compounds concentrations in air   | Superior LaMP - 14 | C.R.(4082)       |
| 4132      | Recreational Water Quality              | Enterococci concentrations in water                | Superior LaMP - 14 | C.R.(4081)       |
| 4133      | Recreational Water Quality              | E. coli concentrations in water                    | Superior LaMP - 14 | C.R.(4081)       |
| 4134      | Recreational Water Quality              | Fecal coliform concentrations in water             | Superior LaMP - 14 | C.R.(4081)       |
| 4135      | Contaminants in Drinking Water          | Viruses in raw and treated water                   | Superior LaMP - 14 | C.R.(4079)       |
| 4136      | Radionuclides                           | XX concentrations in YY                            | Superior LaMP - 14 | No               |
| 4142      | Organochlorines in human breast milk 01 | Concentrations in breast milk of DDT               | Health Canada - 56 | C.R.(4084)       |
| 4143      | Organochlorines in human breast milk 02 | Concentrations in breast milk of dieldrin          | Health Canada - 56 | C.R.(4084)       |
| 4144      | Organochlorines in human breast milk 03 | Concentrations in breast milk of heptachlor epoxid | Health Canada - 56 | C.R.(4084)       |
| 4145      | Organochlorines in human breast milk 04 | Concentrations in breast milk of oxychlordane      | Health Canada - 56 | C.R.(4084)       |
| 4146      | Organochlorines in human breast milk 05 | Concentrations in breast milk of transnonachlor    | Health Canada - 56 | C.R.(4084)       |
| 4147      | Organochlorines in human breast milk 06 | Concentrations in breast milk of B-HCCH            | Health Canada - 56 | C.R.(4084)       |
| 4148      | Organochlorines in human breast milk 07 | Concentrations in breast milk of HCB               | Health Canada - 56 | C.R.(4084)       |
| 4149      | Organochlorines in human breast milk 08 | Concentrations in breast milk of PCB               | Health Canada - 56 | C.R.(4084)       |
| 4150      | Organochlorines in human breast milk 09 | Daily intake of DDT by breast-fed infants          | Health Canada - 56 | C.R.(4084)       |
| 4151      | Organochlorines in human breast milk 10 | Daily intake of dieldrin by breast-fed infants     | Health Canada - 56 | C.R.(4084)       |
| 4152      | Organochlorines in human breast milk 11 | Intake of heptachlor epoxide by breast-fed infants | Health Canada - 56 | C.R.(4084)       |
| 4153      | Organochlorines in human breast milk 12 | Daily intake of oxychlordane by breast-fed infants | Health Canada - 56 | C.R.(4084)       |
| 4154      | Organochlorines in human breast milk 13 | Intake of transnonachlor by breast-fed infants     | Health Canada - 56 | C.R.(4084)       |

| Ind. code | Indicator name  | Measure  | Program sponsor    | SOLEC Indicator? |
|-----------|---|--|--------------------|------------------|
| 4155      | Organochlorines in human breast milk 14               | Daily intake of B-HCCH by breast-fed infants   | Health Canada - 56 | C.R.(4084)       |
| 4156      | Organochlorines in human breast milk 15               | Daily intake of HCB by breast-fed infants  | Health Canada - 56 | C.R.(4084)       |
| 4157      | Organochlorines in human breast milk 16               | Daily intake of PCB by breast-fed infants  | Health Canada - 56 | C.R.(4084)       |
| 4158      | Organochlorines in human breast milk 17               | Organochlorine pesticide index for breast milk   | Health Canada - 56 | C.R.(4084)       |
| 4160      | Geographic distribution of cancer                     | Cancer incidence   | Health Canada - 56 | C.R.(4094)       |
| 4161      | Birth defects in Ontario, 1978-1988                   | Birth defects incidence  | Health Canada - 56 | C.R.(4095)       |
| 4162      | Cancer risk/chlorination disinfection by-products     | THM levels in drinking water + cancer incidence  | Health Canada - 56 | C.R.(4093)       |
| 4163      | Air pollutants affecting hospital admission rates     | Daily respiratory admissions vs sulphate levels  | Health Canada - 56 | C.R.(4091)       |
| 4164      | Air pollutants affecting hospital admission rates     | Daily respiratory admissions vs ozone levels   | Health Canada - 56 | C.R.(4091)       |
| 4165      | Air pollutants affecting hospital admission rates     | Cardiorespiratory hospitalization rates vs levels of sulphates   | Health Canada - 56 | C.R.(4092)       |
| 4166      | Exposure to aldrin and dieldrin                       | Estimated daily intake   | Health Canada - 56 | C.R.(4088)       |
| 4167      | Exposure to benzo(a)pyrene                            | Estimated daily intake   | Health Canada - 56 | C.R.(4088)       |
| 4168      | Exposure to chlordane                                 | Estimated daily intake   | Health Canada - 56 | C.R.(4088)       |
| 4169      | Exposure to DDT                                       | Estimated daily intake   | Health Canada - 56 | C.R.(4088)       |
| 4170      | Exposure to dioxins and furans                        | Estimated daily intake   | Health Canada - 56 | C.R.(4088)       |
| 4171      | Exposure to PCBs                                      | Estimated daily intake   | Health Canada - 56 | C.R.(4088)       |
| 4172      | Exposure to hexachlorobenzene                         | Estimated daily intake   | Health Canada - 56 | C.R.(4088)       |
| 4173      | Exposure to mercury                                   | Estimated daily intake   | Health Canada - 56 | C.R.(4088)       |
| 4174      | Exposure to mirex                                     | Estimated daily intake   | Health Canada - 56 | C.R.(4088)       |
| 4175      | Drinking Water Quality                                | Concentrations of chemical substances such as alkylphenols, metals (e.g., lead, mercury) and other inorganic compounds, pesticides, radionuclides, and drinking water disinfection by-products (e.g., trihalomethanes) as well as microbial parameters such as bacteria, viruses and parasites in raw, treated and distributed drinking water. |                    | Yes              |
| 4176      | Air Quality   | Concentration of chemicals and particulate matter in ambient air.  |                    | Yes              |
| 4177      | Chemical Contaminants in Human Tissue                 | Concentrations of PBT chemicals targeted by the GLWQA in human tissues such as blood, breast milk, hair and adipose tissues.   |                    | Yes              |
| 4178      | Radionuclides   | Concentration of Cs-137 and Sr-90 in cow's milk, gross beta activity in air and precipitation, and airborne and waterborne radionuclide emissions from nuclear power plants in the Great Lakes basin.  |                    | Yes              |
| 4179      | Geographic Patterns and Trends in Disease Incidence   | Disease incidence rate (rate = x disease incidences/ y population) of diseases that have a demonstrated environmental link, such as cancers and birth defects, in the Great Lakes basin.   |                    | Yes              |
| 4501      | Coastal Wetland Invertebrate Community Health         | Functional Feeding Groups (e.g., herbivores, detritivores, carnivores)/Index of Biotic Integrity (IBI)   | Combined           | Yes              |
| 4502      | Coastal Wetland Fish Community Health                 | Index of Biotic Integrity (IBI)  |                    | Yes              |
| 4503      | Deformities/Eroded Fins/Lesions/Tumors (DELT) in Fish | Numbers and percent of deformities/ eroded fins/ lesions/ tumors (DELT) in coastal wetland fish.   |                    | Yes              |
| 4504      | Amphibian Diversity and Abundance                     | Species composition and relative abundance of calling frogs and toads, based on evening surveys using protocol developed for the Marsh Monitoring Program (MMP) or modification of MMP protocol.   |                    | Yes              |

| Ind. code | Indicator name  | Measure   | Program sponsor                 | SOLEC Indicator?     |
|-----------|---|---|---------------------------------|----------------------|
| 4505      | Reptile Diversity and Abundance                       | Species composition and abundance of basking turtles and snakes, based on surveys using protocol similar to the Marsh Monitoring Program (MMP) protocols for amphibian and bird surveys.  |                                 | No                   |
| 4506      | Contaminants in Snapping Turtle Eggs                  | Contaminant levels in Snapping Turtle eggs  |                                 | Yes                  |
| 4507      | Wetland-dependent Bird Diversity and Abundance        | Species composition and relative abundance of wetland-dependent birds, based on evening surveys using protocol developed for Marsh Monitoring Program (MMP) or modification of the MMP protocol.  |                                 | Yes                  |
| 4508      | Mink Populations                                      | Estimate of numbers of mink   |                                 | No                   |
| 4509      | Contaminants in Mink                                  | Measure levels of contaminants in wild mink of Great Lakes coastal wetlands.  |                                 | No                   |
| 4510      | Coastal Wetland Area by Type                          | Areal extent of coastal wetlands by type as a range (e.g., dry year/low water level area versus wet year/ high water level area).   | USEPA - 47                      | Yes                  |
| 4511      | Gain in Restored Coastal Wetland Area by Type         | Gain in restored wetland area by type.  | SOLEC                           | Yes                  |
| 4512      | Chlorophyll a Levels                                  | Chlorophyll a levels  | SOLEC                           | No                   |
| 4513      | Presence, Abundance & Expansion of Invasive Plants    | Presence, abundance, & expansion of invasive plants, such as flowering rush, great hairy willow-herb, common frogbit, yellow iris, purple loosestrife, Eurasian water milfoil, curly pondweed, cattail, Phalaris, and Phragmites.   | EC/TNC - 42                     | Yes                  |
| 4514      | Agricultural land use: risk of declining soil quality | Areas at risk of declining soil quality (primarily erosion) are calculated/estimated from their inherent soil loss (under natural cover), topography/slope, the type of crop grown, and agricultural management practices (e.g. conservation tillage).  | Great Lakes Commission – 53     | C.R.(7007)           |
| 4515      | Reported Toxic Releases                               | Total tons of reported toxic releases to water.   |                                 | C.R.(4854,4855,4856) |
| 4516      | Sediment Flowing Into Coastal Wetlands                | Suspended Sediment Unit Area Load (tonnes/km <sup>2</sup> of upstream watershed) for a representative set of existing monitoring sites just upstream of coastal wetlands.   | EC/TNC - 42, EC & partners - 43 | Yes                  |
| 4517      | Inflow Flow Alteration                                | Ratio of total high extreme flows to total low extreme flows for all existing monitoring sites just upstream of coastal wetlands.   |                                 | No                   |
| 4518      | Water Level Fluctuations                              | Using IGLD 85 water levels and gauging stations best representing lakes and coastal wetlands: 1) Weighted 5-year moving average level index = $[0.5 L(t) + 0.25 L(t-1) + 0.125 L(t-2) + 0.0625 L(t-3) + 0.03125 L(t-4)] / 0.96875$ , where L(t) is the average lake level in year t (Busch, 1990). 2) Lake-wide annual range in monthly averages. 3) Lake-wide seasonal peak (days after January 1). 4) Lake-wide seasonal minimum (days after September 1). 5) Elevation Difference between Upper and Lower Emergent Extent based on Water Level model (Painter & Keddy, 1992). (Upper extent uses average water level surrounding seasonal peak of growing season (e.g., May, June, July average). Upper extent follows this value for rising levels and stays at the highest for 12 years after levels drop and then within 6 years meets the water level. Lower extent uses the mean water level in September. Lower extent follows mean September levels as they drop. As levels rise, it takes 3 years to move up to meet mean September levels.) |                                 | C.R.(4861)           |
| 4519      | Global Warming: Number of Extreme Storms              | For land areas adjacent to the Great Lakes, total number of "extreme storms", per year during ice-free and ice-break-up periods on the Great Lakes.   |                                 | Yes                  |
| 4520      | Development Adjacent to Representative Wetlands       |   |                                 | No                   |
| 4521      | Buffers and Land Use Adjacent to Coastal Wetlands     | Sum of a weighted score of adjacent land use using km perimeter x weighting factor divided by the total upland perimeter, where the weighting factors are: Built-up = -1; Row Crop = -0.5; Hay and pasture = -0.2. Where buffers (idle or wooded): Buffer of >1000 m and Land Use beyond buffer: Urban = 1, Row Crop = 1, Hay and Pasture = 1. Buffer of 250 - 1000 m and Land Use beyond buffer: Urban = 0.25, Row Crop = 0.5, Hay and Pasture = 0.8. Buffer of 50 - 250 m and Land Use beyond buffer: Urban = 0.1, Row Crop = 0.2, Hay and Pasture = 0.5. Buffer of 20 - 50 m and Land Use beyond buffer: Urban = 0.05, Row Crop = 0.1, Hay and Pasture = 0.25.   |                                 | C.R.(7054)           |

| Ind. code | Indicator name  | Measure   | Program sponsor    | SOLEC Indicator? |
|-----------|---|---|--------------------|------------------|
| 4522      | Upstream Buffers and Agricultural Land Use  |   |                    | No               |
| 4523      | Inflow Water Quality: Invertebrate Indices  | Area-weighted total of each bioMAP for streams (river mouth wetlands) and Reynoldson's Nearshore Index (open shore wetlands), and possibly on-site turbidity. |                    | No               |
| 4524      | First Emergence of Indicator spp or Ice Duration  | Average emergence of an indicator species; average duration of ice cover.   |                    | C.R.(4857,4858)  |
| 4525      | Quantity and quality of wetlands  |   | EC & partners - 43 | No               |
| 4526      | Quantity and quality of wetlands  |   | IJC - 35           | No               |
| 4527      | Quantity and quality of particular habitat  |   | EC & partners - 43 | No               |
| 4528      | Quantity and quality of particular habitat types (e.g. wetlands and spawning beds for desirable native species)               |   | IJC - 35           | No               |
| 4529      | Areal Extent of Wetlands (meadow-emergent area)   |   | USEPA - 48         | No               |
| 4530      | Wetland Extent & Type Diversity (C.2)   | Changes in aerial extent and diversity of vegetation types using aerial photos  | USEPA - 47         | No               |
| 4531      | Hexagon-wide Areal Extent of Wetlands   |   | USEPA - 48         | No               |
| 4532      | Wetland size, abundance   |   | SOLEC - 28         | No               |
| 4533      | Wetland habitat   | Number and area   | SOLEC - 27         | No               |
| 4534      | Size, Position, and Number of Great Lakes Coastal Wetlands  |   | SOLEC - 25         | No               |
| 4535      | Wetland Size, Abundance, and Susceptibility to Threats Along its Border   |   | SOLEC - 24         | No               |
| 4536      | Areal Extent of Wetland Type  |   | USEPA - 48         | No               |
| 4537      | Acres of shoreline wetlands with diverse submergent and emergent macrophyte growth that can provide spawning habitat for fish |   | Michigan LaMP - 9  | No               |
| 4538      | Changes in Area of Habitats or Vegetation Types Over Time   |   | SOLEC - 25         | No               |
| 4539      | Average Area per Wetland  |   | USEPA - 48         | No               |
| 4540      | Area of relative % area of physical features of watershed based on mapping  |   | EC & partners - 43 | No               |
| 4541      | Number of Wetlands/Unit Area  |   | USEPA - 48         | No               |
| 4542      | Mapping: Wetland Spatial Configuration  |   | USEPA - 48         | No               |
| 4543      | Patch Size and Perimeter-to-Area Ratio  | Measurements of patch areas and perimeters from aerial photos (GIS for large areas)   | USEPA - 47         | No               |
| 4544      | Fractal Dimension (index of complexity of shapes on the landscape)  | Calculation involving perimeter and area for patches on a digitized map   | USEPA - 47         | No               |
| 4545      | Shape Index (perimeter vs perimeter of circle the same area)  |   | USEPA - 48         | No               |
| 4546      | Patton's Diversity Index  | A measure of the amount of edge within an area of given size from aerial photos   | USEPA - 47         | No               |
| 4547      | Compliance with protection of wetlands  |   | EC & partners - 43 | No               |
| 4548      | Number of regulations relating to habitat protection  |   | EC & partners - 43 | No               |
| 4549      | Protection of the Collingwood Wetland Complex   |   | EC & partners - 43 | No               |
| 4550      | Amount of protected spaces versus total area  |   | EC & partners - 43 | No               |
| 4551      | Percent of land covered by historical property protection   |   | EC & partners - 43 | No               |
| 4552      | Habitat loss or restoration   |   | EC & partners - 43 | No               |

| Ind. code | Indicator name   | Measure   | Program sponsor    | SOLEC Indicator? |
|-----------|--|---|--------------------|------------------|
| 4553      | Rates of loss of particular habitat types  |   | EC & partners - 43 | No               |
| 4554      | Loss in habitat/wetlands quality & quantity  |   | SOLEC - 22         | No               |
| 4555      | Acres restored to wetland condition - net gain   |   | EC & partners - 43 | No               |
| 4556      | Amount of habitat enhancement remediation  |   | EC & partners - 43 | No               |
| 4557      | Gains in habitat/wetlands quality & quantity (areas protected)   |   | SOLEC - 22         | No               |
| 4558      | Range of expansion or reduction of exotic and native species   |   | EC & partners - 43 | No               |
| 4559      | A Habitat Index based on concept of IBI (Index of Biotic Integrity)  |   | EC & partners - 43 | No               |
| 4560      | Resilience - time of recovery of system health following an extreme event/occurrence   |   | EC & partners - 43 | No               |
| 4561      | Interspersion of wetland vegetation and open water (wetland spatial config. - interspersion & water depths)  |   | USEPA - 48         | No               |
| 4562      | Habitat Proportions (Cover Types)  | Mapping and determining proportions of various land use or vegetation cover types in a landscape using remotely sensed data   | USEPA - 47         | C.R.(4521)       |
| 4563      | Fish and wildlife habitat  |   | EC & partners - 43 | No               |
| 4564      | Presence of suitable fish habitat  |   | USEPA - 48         | No               |
| 4565      | Quantity and quality of habitat throughout the life cycle for critical components of the food web; information about productivity and submerged vegetation may be useful |   | IJC - 35           | No               |
| 4566      | Quantity and quality of habitat throughout the life cycle for critical components of the food web  |   | EC & partners - 43 | No               |
| 4567      | Effect of exotic species   |   | SOLEC - 28         | No               |
| 4568      | Measure of habitat connectiveness (roads, fences, canals, etc.)  |   | EC & partners - 43 | C.R.(4521)       |
| 4569      | Gamma Index of Network Connectivity  | Ratio of links in a network to the maximum possible number of links in that network from remotely sensed data   | USEPA - 47         | No               |
| 4570      | Structural Diversity (# veg communities/unit area)   |   | USEPA - 48         | No               |
| 4571      | Abundance, Diversity, & Species Composition of Vegetation (C.3)  | Other metrics: aerial cover, species richness, relative abundance, relative dominance, importance values, diversity, presence/ absence of indicator species, & spatial patterning | USEPA - 47         | No               |
| 4572      | Extent of submerged aquatic vegetation (distribution)  |   | EC & partners - 43 | No               |
| 4573      | Vegetation Structure   |   | USEPA - 48         | No               |
| 4574      | Linear Classification & Physical Structure of Habitat  | Vertical vegetation profile   | USEPA - 47         | No               |
| 4575      | Permanent vegetation plots   |   | EC & partners - 43 | No               |
| 4576      | Biomass (or production) size spectrum  |   | EC & partners - 43 | No               |
| 4577      | Plant community characteristics (dominance & diversity of indicator species)   |   | USEPA - 48         | No               |
| 4578      | Changes in Plant Community Characteristics   |   | SOLEC - 25         | No               |
| 4579      | Status of plant communities  |   | SOLEC - 28         | No               |
| 4580      | Status of Plant Communities  |   | SOLEC - 24         | No               |
| 4581      | Productivity/ Population Viability - Plants:   | Pitcher's Thistle in low dunes, Lake Huron Tansy  | Michigan LaMP - 8  | No               |
| 4582      | Plant performance  |   | USEPA - 48         | No               |
| 4583      | Status of individual plant species   |   | SOLEC - 28         | No               |



| Ind. code | Indicator name  | Measure   | Program sponsor    | SOLEC Indicator? |
|-----------|---|---|--------------------|------------------|
| 4584      | Status of Individual Plant Taxa   |   | SOLEC - 24         | No               |
| 4585      | Leaf Area, Solar Transmittance, & Greenness   | Changes in canopy characteristics (e.g., premature leaf drop and yellowing of leaves) and solar transmittance   | USEPA - 47         | No               |
| 4586      | Algae blooms  |   | EC & partners - 43 | No               |
| 4587      | August diatom to blue green algae ratio   |   | EC & partners - 43 | No               |
| 4588      | Chlorophyll a (as indicator of nuisance algal growth)   |   | SOLEC - 22         | No               |
| 4589      | Number of species present from a selected list of conservative wetland obligate marsh species   |   | EC/TNC - 42        | No               |
| 4590      | Floristic Quality Assessment  |   | EC/TNC - 42        | No               |
| 4591      | Number of species present from a selected list of weedy marsh species   | Selected list includes: flowering rush, great hairy willow-herb, common frogbit, yellow iris, purple loosestrife, Eurasian water milfoil, curly pond weed | EC/TNC - 42        | No               |
| 4592      | Index of amount and extent of plant detritus (depth of litter above soil)   |   | USEPA - 48         | No               |
| 4593      | Marsh Monitoring Program (presence of indicator bird and amphibian species)   |   | EC/TNC - 42        | No               |
| 4594      | Results of Breeding Bird Survey   |   | Michigan LaMP - 8  | No               |
| 4595      | Biodiversity Measurements   |   | SOLEC - 25         | No               |
| 4596      | Biotic Community Indices  |   | SOLEC - 25         | No               |
| 4597      | Shannon and Simpson Index   |   | Michigan LaMP - 8  | No               |
| 4598      | Changes in Richness - types of organisms with respect to air/water/land interfaces  |   | EC & partners - 43 | No               |
| 4599      | Species Richness and Berger-Parker  |   | Michigan LaMP - 8  | No               |
| 4600      | Species richness (maintain healthy commercial and recreational fisheries)   |   | EC & partners - 43 | No               |
| 4601      | Species Diversity (alpha, community) (wildlife)   |   | USEPA - 48         | No               |
| 4602      | Status of basin diversity   |   | EC & partners - 43 | No               |
| 4603      | Regional Diversity (Beta, ecosystem)  |   | USEPA - 48         | No               |
| 4604      | Changes in Faunal Community Characteristics   |   | SOLEC - 25         | No               |
| 4605      | Integrity of biotic communities   |   | EC & partners - 43 | No               |
| 4606      | Percentage of optimum population density - specific species   |   | EC & partners - 43 | No               |
| 4607      | Presence and relative abundance of key aquatic species  |   | EC & partners - 43 | No               |
| 4608      | Change in keystone or unique species  |   | EC & partners - 43 | No               |
| 4609      | Changes in unique species   |   | EC & partners - 43 | No               |
| 4610      | Demographics: Animals   | Age structure, sex ratio, fertility, mortality, survivorship, and dispersal of keystone species   | USEPA - 47         | No               |
| 4611      | Presence and abundance of selected key species within the food web, including a top predator, a mid-trophic level species, and a species at the food base |   | EC & partners - 43 | No               |
| 4612      | Productivity of certain species - bald eagle, black bear  |   | EC & partners - 43 | No               |
| 4613      | Trophic structures and flux / Number/abundance/status of species representing various trophic levels or guilds  |   | EC & partners - 43 | No               |
| 4614      | Wildlife populations  | Species and population  | SOLEC - 27         | No               |

| Ind. code | Indicator name   | Measure   | Program sponsor    | SOLEC Indicator? |
|-----------|--|---|--------------------|------------------|
| 4615      | Self-sustaining indigenous species, survival, growth, and food habits                              |   | EC & partners - 43 | No               |
| 4616      | Presence of Rare, Threatened, or Endangered Species  | Selected list includes: Wood Turtle, Blanding's Turtle, W. and N. Ribbon Snake, Queen Snake, E. Massasauga  | Michigan LaMP - 8  | No               |
| 4617      | Number and abundance of endangered native species, incl. fish, waterfowl, plants and invertebrates |   | IJC - 35           | No               |
| 4618      | Threatened or endangered species or habitats   |   | EC & partners - 43 | No               |
| 4619      | Population density of provincially significant bird species  |   | EC & partners - 43 | No               |
| 4620      | Population Characteristics of Economically or Socially Valuable Wetland Species                    |   | SOLEC - 25         | No               |
| 4621      | Presence of Characteristic Species with Narrow Environmental Tolerances                            |   | SOLEC - 25         | No               |
| 4622      | Status of Species Typical of a Great Lakes Wetland   |   | SOLEC - 24         | No               |
| 4623      | Detection of new species and establishment of self-sustaining populations                          |   | EC & partners - 43 | No               |
| 4624      | Natural reproduction   |   | EC & partners - 43 | No               |
| 4625      | Costs of exotic species  |   | EC & partners - 43 | No               |
| 4626      | Presence and abundance of non-indigenous species   |   | EC & partners - 43 | No               |
| 4627      | Status of Exotic Species   |   | SOLEC - 24         | No               |
| 4628      | Native species loss (# native species)   |   | SOLEC - 22         | No               |
| 4629      | Rates of extinction  |   | EC & partners - 43 | No               |
| 4630      | Number and abundance of native species vs introduced or invading species                           |   | EC & partners - 43 | No               |
| 4631      | Non-native species (stressor and effect)   |   | EC/TNC - 42        | No               |
| 4632      | Cumulative number and abundance of exotic species introduced                                       |   | IJC - 35           | No               |
| 4633      | Presence and Abundance of Invasive Species   |   | SOLEC - 25         | No               |
| 4634      | Population densities of wildlife including waterfowl   |   | EC & partners - 43 | No               |
| 4635      | Relative Abundance: Animals  | Presence of certain water bird species; usefulness of other classes of animals being evaluated  | USEPA - 47         | No               |
| 4636      | Migrating waterfowl counts   |   | EC/TNC - 42        | No               |
| 4637      | Number of pairs of colonial waterbirds   |   | EC & partners - 43 | No               |
| 4638      | Population size  |   | EC & partners - 43 | No               |
| 4639      | Reproductive potential (egg size, clutch or brood size)  |   | EC & partners - 43 | No               |
| 4640      | Productivity (young produced and raised to independence)   |   | EC & partners - 43 | No               |
| 4641      | Neotropical bird abundance and diversity   |   | EC & partners - 43 | No               |
| 4642      | Productivity Metrics - Birds   | Bald Eagle, 1200 northern breeding pairs -- minimum production of 1.0 young per nest; terns, Black-crowned Night-Heron, cormorants -- nest production   | Michigan LaMP - 8  | No               |
| 4643      | Stress Resistance - Birds  | Bald Eagles (for northern Lake Michigan), terns, Black-crowned Night-Herons -- genetic diversity, disease incidence, immune function, stress biomarkers | Michigan LaMP - 8  | No               |
| 4644      | Age structure of the population  |   | EC & partners - 43 | No               |

| Ind. code | Indicator name   | Measure   | Program sponsor    | SOLEC Indicator? |
|-----------|--|---|--------------------|------------------|
| 4645      | Productivity Metrics - Insects   | Biomass by species or guild (emergent, sediment-dwelling, surface, etc.)  | Michigan LaMP - 8  | No               |
| 4646      | Amphibian abundance, species richness, and species composition   |   | EC & partners - 43 | No               |
| 4647      | Productivity Metrics - Amphibians  | # of Mud Puppy egg masses and % hatching; # of larvae and survival, # of adults   | Michigan LaMP - 8  | No               |
| 4648      | Stress Resistance - Amphibians   | Mud Puppy -- genetic diversity, disease incidence, immune function, stress biomarkers   | Michigan LaMP - 8  | No               |
| 4649      | Amphibian Assemblage Diversity   |   | Michigan LaMP - 8  | No               |
| 4650      | Productivity Metrics - Reptiles  | # of Snapping Turtle eggs and # of Painted Turtle eggs; # of adult Snapping Turtles and # of adult Painted Turtles; incidence of dead embryos and deformities | Michigan LaMP - 8  | No               |
| 4651      | Stress Resistance - Reptiles   | Snapping Turtles and Painted Turtles -- genetic diversity, disease incidence, immune function, stress biomarkers  | Michigan LaMP - 8  | No               |
| 4652      | Reptile Assemblage Diversity   |   | Michigan LaMP - 8  | No               |
| 4653      | Productivity/ Population Viability - Mammals   | Mink -- # of offspring and survival, incidence of dead embryos and deformities  | Michigan LaMP - 8  | No               |
| 4654      | Stress Resistance - Mammals  | Mink -- genetic diversity, disease incidence, immune function, stress biomarkers  | Michigan LaMP - 8  | No               |
| 4655      | Ungulate range in the Lake superior basin  |   | EC & partners - 43 | No               |
| 4656      | Number and saturation of niches present  |   | EC & partners - 43 | No               |
| 4657      | Faunal indicators of disturbed habitat   |   | USEPA - 48         | No               |
| 4658      | Population Survival & Mortality  |   | USEPA - 48         | No               |
| 4659      | Benthic invertebrates (avoid destructive land-water linkages)  |   | EC & partners - 43 | No               |
| 4660      | Shift in oligochaete assemblages & midges, fingernail clams, mayflies, amphipods, indicative of eutrophic environment to mesotrophic environment |   | EC & partners - 43 | No               |
| 4661      | Benthos  |   | EC & partners - 43 | No               |
| 4662      | Acute and chronic toxic effects on benthic community absent  |   | EC & partners - 43 | No               |
| 4663      | Bioassay of benthic community show end points comparable to controls   |   | EC & partners - 43 | No               |
| 4664      | Benthic biomass ranging from 25 to 50 g/m wet weight of benthos  |   | EC & partners - 43 | No               |
| 4665      | Population densities of mesotrophic species  |   | EC & partners - 43 | No               |
| 4666      | Benthic community structure not significantly different from control sites of desirable physical and chemical characteristics                    |   | EC & partners - 43 | No               |
| 4667      | Sediment Particle Size Distribution  |   | USEPA - 48         | No               |
| 4668      | Aquatic Invertebrate community - multiple metrics  |   | USEPA - 48         | No               |
| 4669      | Aquatic insect emergence rate (# tax & indiv. / unit time)   |   | USEPA - 48         | No               |
| 4670      | Deviation from expected benthic community  |   | USEPA - 48         | No               |
| 4671      | Paleoindicators  |   | USEPA - 48         | No               |
| 4672      | Macroinvertebrate Abundance, Biomass, & Species Composition  |   | USEPA - 47         | No               |
| 4673      | Soil & Aquatic Microbial Community Structure   |   | USEPA - 47         | No               |
| 4674      | Reach specific & basin-wide fish assemblage assessment: species composition, relative abundance, movement, critical habitat identification       |   | EC & partners - 43 | No               |

| Ind. code | Indicator name   | Measure | Program sponsor    | SOLEC Indicator?            |
|-----------|--|---------|--------------------|-----------------------------|
| 4675      | Species: Northern Pike, Yellow Perch, Brown Bullhead   |         | USEPA - 48         | No                          |
| 4676      | Fish Community Stability   |         | USEPA - 48         | No                          |
| 4677      | Shift from a fish community indicative of eutrophic environment to a self-sustaining community   |         | EC & partners - 43 | No                          |
| 4678      | Ratio biomass piscivores to prey fish biomass  |         | EC & partners - 43 | No                          |
| 4679      | Proposed nearshore biomass (kg/ha): piscivores 40-60; specialists: 70-100; generalists 30-90   |         | EC & partners - 43 | No                          |
| 4680      | Fraction of salmonine production comprising naturally produced fish  |         | EC & partners - 43 | No                          |
| 4681      | Balanced fishery and nutrients   |         | EC & partners - 43 | No                          |
| 4682      | Increase the (fish) species richness from 4 to 6-7 per transect  |         | EC & partners - 43 | No                          |
| 4683      | Abundance/Biomass (fish)   |         | USEPA - 48         | No                          |
| 4684      | Species Abundance/Diversity (fish)   |         | USEPA - 48         | No                          |
| 4685      | Diversity (fish)   |         | USEPA - 48         | No                          |
| 4686      | Pelagic: Benthic Ratio (fish)  |         | USEPA - 48         | No                          |
| 4687      | Increase the native (fish) species biomass from 37% to 80-90% of the total biomass   |         | EC & partners - 43 | No                          |
| 4688      | Percent Exotics (fish)   |         | USEPA - 48         | No                          |
| 4689      | Percent of Rough Fish (Biomass) in Community   |         | USEPA - 48         | No                          |
| 4690      | Percent Phytophils (fish)  |         | USEPA - 48         | No                          |
| 4691      | Predator:Prey Ratio (fish)   |         | USEPA - 48         | No                          |
| 4692      | Percent of Turbidity tolerant species in community (fish)  |         | USEPA - 48         | No                          |
| 4693      | Production of yield piscivores   |         | EC & partners - 43 | No                          |
| 4694      | Hatchery production  |         | EC & partners - 43 | No                          |
| 4695      | Viable recruitment   |         | EC & partners - 43 | No                          |
| 4696      | Attain a littoral fish biomass of 200-250 kg/ha  |         | EC & partners - 43 | No                          |
| 4697      | Reduce the spatial variability in fish biomass   |         | EC & partners - 43 | No                          |
| 4698      | Healthy fish communities present indicating a viable plankton community  |         | EC & partners - 43 | No                          |
| 4699      | Fish harvest statistics vs spawning biomass levels   |         | EC & partners - 43 | No                          |
| 4700      | Fish harvest statistics vs. spawning biomass levels  |         | IJC - 35           | No                          |
| 4701      | Fish catch   |         | EC/TNC - 42        | No                          |
| 4702      | Total standing stock/secondary production (fish)   |         | USEPA - 48         | No                          |
| 4703      | Commercial Fish Catches of Wetland-dependent Species   |         | SOLEC - 25         | No                          |
| 4704      | Changes in sediment budgets, nutrient enrichment, toxic chemicals (BioMAP stream benthic index, Reynoldson's nearshore benthic index, % upland-wetland interface that is buffered) |         | EC/TNC - 42        | C.R.(4516,4 854,4855,48 56) |
| 4705      | Acid loadings  |         | EC & partners - 43 | No                          |
| 4706      | Quality/quantity of dredged material   |         | EC & partners - 43 | No                          |

| Ind. code | Indicator name  | Measure   | Program sponsor    | SOLEC Indicator?       |
|-----------|---|---|--------------------|------------------------|
| 4707      | Loss of habitat specific to persistent toxics   |   | EC & partners - 43 | No                     |
| 4708      | Model fate and distribution of suspended sediment/contaminant   |   | EC & partners - 43 | C.R.(4516)             |
| 4709      | Contaminant fate model - TOXIWASP   |   | EC & partners - 43 | No                     |
| 4710      | Develop/improve DO modeling capabilities - DOSTOC, WASP   |   | EC & partners - 43 | No                     |
| 4711      | Bioassays   | Laboratory testing of pollutant effects on organisms    | USEPA - 47         | No                     |
| 4712      | Fish and wildlife bioassays confirm no significant toxicity from the water column or sediment contaminants / Contaminant levels in wildlife                     |   | EC & partners - 43 | No                     |
| 4713      | Algal bioassays show no significant differences in toxicity between harbour and control samples   |   | EC & partners - 43 | No                     |
| 4714      | Chemical Contaminants in Water & Sediments  |   | USEPA - 47         | No                     |
| 4715      | Field monitoring of water column contaminants   |   | EC & partners - 43 | No                     |
| 4716      | Toxins  |   | USEPA - 48         | No                     |
| 4717      | Levels of nutrients and persistent toxic chemicals  |   | SOLEC - 28         | C.R.(4854, 4855, 4856) |
| 4718      | Concentrations of Nutrients and Toxic Substances  |   | SOLEC - 25         | C.R.(4854, 4855, 4856) |
| 4719      | Levels of Persistent Toxic Chemicals  |   | SOLEC - 24         | No                     |
| 4720      | Concentration of Persistent Toxic Substances in Biota   |   | SOLEC - 24         | No                     |
| 4721      | Concentration of persistent toxic substances in biota   |   | SOLEC - 28         | No                     |
| 4722      | Chemical Contaminants in Tissues  | Contaminant bioaccumulation in plant and animal tissues | USEPA - 47         | No                     |
| 4723      | Contaminant Accumulation (wildlife)   |   | USEPA - 48         | No                     |
| 4724      | Contaminant levels in tissue population growth rates and density in most sensitive species equal to that of control areas                                       |   | EC & partners - 43 | No                     |
| 4725      | Toxic contaminants in aquatic organisms   |   | EC & partners - 43 | No                     |
| 4726      | Tissue Concentrations of Toxic Chemicals or Malformation in Fish and Wildlife   |   | SOLEC - 25         | No                     |
| 4727      | Concentration of contaminants in fish   |   | EC & partners - 43 | No                     |
| 4728      | Levels of toxic contaminants in fish  |   | EC & partners - 43 | No                     |
| 4729      | White sucker - population characteristics, reproductive success, tumors, EROD/AHH or Caffeine Breath Test, BROD/PROD, Vitamin A stores, DNA damage, Plasma ALAD |   | IJC - 36           | No                     |
| 4730      | Abnormalities/Pathology in Brown Bullhead   |   | USEPA - 48         | No                     |
| 4731      | Contaminant Load in Brown Bullhead Fillet   |   | USEPA - 48         | No                     |
| 4732      | Toxic contaminant levels in selected fish species and in selected fish-eating birds   |   | IJC - 35           | No                     |
| 4733      | Productivity Metrics - Birds:   | Herring Gull contaminant levels                         | Michigan LaMP - 8  | No                     |
| 4734      | Bald Eagle abundance and contamination  |   | EC & partners - 43 | No                     |

| Ind. code | Indicator name   | Measure  | Program sponsor    | SOLEC Indicator? |
|-----------|--|--|--------------------|------------------|
| 4735      | Bald Eagle - population characteristics, reproductive success, chick growth, congenital abnormalities, eggshell thinning, Caffeine breath Test, Vitamin A stores in plasma, Plasma Thyroxine, Plasma ALAD.             |  | IJC - 36           | No               |
| 4736      | Contaminant Metrics - Birds  | Bald Eagle (for northern Lake Michigan), terns, Black-crowned Night-Heron, cormorants -- concentration of contaminants, enzyme induction assays  | Michigan LaMP - 8  | No               |
| 4737      | Herring gull or Black-crowned night heron - population characteristics, reproductive success, chick growth, congenital abnormalities, EROD/AHH or Caffeine breath Test, PROD/BROD, Vitamin A stores, Plasma Thyroxine. |  | IJC - 36           | No               |
| 4738      | Double-crested cormorant - population characteristics, congenital abnormalities, eggshell thinning   |  | IJC - 36           | No               |
| 4739      | Contaminants in Feathers   |  | USEPA - 48         | No               |
| 4740      | Contaminant Metrics - Plants   | Pitcher's Thistle in low dunes; Lake Huron Tansy   | Michigan LaMP - 8  | No               |
| 4741      | Contaminant Metrics - Amphibians   | Mud Puppy -- concentration of contaminants, enzyme induction assays  | Michigan LaMP - 8  | No               |
| 4742      | Contaminant Metrics - Reptiles   | Snapping Turtles and Painted Turtles -- concentration of contaminants, enzyme induction assays   | Michigan LaMP - 8  | No               |
| 4743      | Snapping turtle - Population characteristics, Reproductive success, Congenital anomalies, DNA damage   |  | IJC - 36           | No               |
| 4744      | Contaminant Metrics - Mammals  | Mink -- concentration of contaminants, enzyme induction assays   | Michigan LaMP - 8  | No               |
| 4745      | Mink - Population characteristics, Reproductive success  |  | IJC - 36           | No               |
| 4746      | Acetyl Cholinesterase - AChE (sub-organism)  |  | USEPA - 48         | No               |
| 4747      | ALAD (sub-organism) (blood enzyme)   |  | USEPA - 48         | No               |
| 4748      | Species health   |  | EC & partners - 43 | No               |
| 4749      | Detoxifying Enzyme Systems (sub-organisms)   |  | USEPA - 48         | No               |
| 4750      | Species Specific Individual Pathology  |  | USEPA - 48         | No               |
| 4751      | Gene Frequency   |  | USEPA - 48         | No               |
| 4752      | Genetic Damage   |  | USEPA - 48         | No               |
| 4753      | Immuno Assay (sub-organism)  |  | USEPA - 48         | No               |
| 4754      | species specific Individual Diet   |  | USEPA - 48         | No               |
| 4755      | Species-specific Individual Body Weight / Condition Index  |  | USEPA - 48         | No               |
| 4756      | Species - specific individual behaviour  |  | USEPA - 48         | No               |
| 4757      | Natural Biological Stressors (e.g. count # muskrat houses in sample area)  |  | EC/TNC - 42        | No               |
| 4758      | Morphological Asymmetry: Animals   | Morphological variability in structure such as teeth and bones of bilaterally symmetrical organisms  | USEPA - 47         | No               |
| 4759      | Biomarkers (broad indicator covered more specifically in next 8 indicators)  | Organism response to human-induced stresses at the biochemical and cellular level before the stresses produce a detectable response at the organism and population levels  | USEPA - 47         | No               |
| 4760      | DNA Alteration: Adducts  | Lab analysis for DNA adducts indicating exposure to chemical(s); with sufficient toxicological information and identification of particular adducts, data obtained may be a diagnostic screening technique for environmental genotoxicity. | USEPA - 47         | No               |

| Ind. code | Indicator name   | Measure  | Program sponsor    | SOLEC Indicator? |
|-----------|--|--|--------------------|------------------|
| 4761      | DNA Alteration:Secondary Modification  | Lab analysis for strand breaks in DNA; screening technique for exposure to any genotoxic chemical.   | USEPA - 47         | No               |
| 4762      | DNA Alteration: Irreversible Event   | Lab analysis for irreversible DNA alteration; screening technique that indicates subclinical expression of mutagenic damage.   | USEPA - 47         | No               |
| 4763      | Cholinesterase Levels  | Lab analysis for neurotoxic chemicals such as organophosphates and carbamates (insecticides).  | USEPA - 47         | No               |
| 4764      | Metabolites of Xenobiotic Chemicals  | Lab analysis for certain metabolites of xenobiotic chemicals in animals; confirms that toxicants have entered cells and interacted with molecular targets.   | USEPA - 47         | No               |
| 4765      | Porphyrin Accumulation   | Lab analysis of porphyrins; patterns of accumulation may be used to predict action of chemicals within the pathway of heme biosynthesis, which is vital for maintaining adequate blood cell count; PCBs, Pb may disturb porphyrin metabolism in mammals & birds. | USEPA - 47         | No               |
| 4766      | Histopathologic Alterations  | Extensive methodology exists for determination of tissue, cellular and subcellular responses as an indicator of exposure to a variety of anthropogenic pollutants  | USEPA - 47         | No               |
| 4767      | Fish Consumption Advisories for Wetland-dependent Species  |  | SOLEC - 25         | No               |
| 4768      | Certain Health Problems Associated with Consumption Rates of Plants, Fish, or Wildlife from Coastal Wetlands |  | SOLEC - 25         | No               |
| 4769      | Macrophage Phagocytotic Activity   | Lab analysis of uptake of formalin-killed E. coli by macrophages; indicator of immune system capacity to destroy foreign material can serve as a useful sentinel of the health status of environmentally stressed organisms                                      | USEPA - 47         | No               |
| 4770      | Water column nutrient levels   |  | EC & partners - 43 | C.R.(4855, 4856) |
| 4771      | Nutrients in Water & Sediments   |  | USEPA - 47         | C.R.(4855, 4856) |
| 4772      | Nutrient diffusing substrates/periphyton   |  | EC & partners - 43 | No               |
| 4773      | Field monitoring of water column SOD   |  | EC & partners - 43 | No               |
| 4774      | Algal blooms, which characterize excess nutrient condition   |  | IJC - 35           | No               |
| 4775      | Concentration of total phosphorus  |  | EC & partners - 43 | C.R.(4856)       |
| 4776      | Loadings of phosphorus   |  | EC & partners - 43 | C.R.(4856)       |
| 4777      | Changes in recreational activity due to excess phosphorus  |  | EC & partners - 43 | No               |
| 4778      | Ambient phosphorus concentrations  |  | IJC - 35           | C.R.(4856)       |
| 4779      | Ambient phosphorus concentration in selected areas of the Great Lakes  |  | IJC - 35           | C.R.(4856)       |
| 4780      | Tributary nitrates concentration   |  | EC & partners - 43 | C.R.(4780)       |
| 4781      | Ratio of nitrogen to phosphorus  |  | EC & partners - 43 | No               |
| 4782      | Dissolved oxygen standard (nearshore)  |  | EC & partners - 43 | No               |
| 4783      | Costs for additional mitigation of nutrient loadings for increased point and non-point source control        |  | EC & partners - 43 | No               |
| 4784      | Set initial and final goals of phosphorus, ammonia and suspended solids net loading targets (kg/d)           |  | EC & partners - 43 | C.R.(4516, 4856) |
| 4785      | Nutrient balance (ratio of ammonia & nitrates to total N, of SRP to total P at outlet and inlet)             |  | USEPA - 48         | No               |
| 4786      | Standing Stock of Major Nutrients (CNP analysis of biomass)  |  | USEPA - 48         | No               |
| 4787      | Sediment Nutrient Constituents   |  | USEPA - 48         | No               |
| 4788      | Turbidity  |  | USEPA - 48         | C.R.(4516)       |

| Ind. code | Indicator name   | Measure   | Program sponsor    | SOLEC Indicator?             |
|-----------|--|---|--------------------|------------------------------|
| 4789      | Water quality of harbour and tributary streams   |   | EC & partners - 43 | C.R.(4516, 4854, 4855, 4856) |
| 4790      | Aquatic Conditions, Diurnal DO/pH, Alkalinity, Temperature, Turbidity & (P/R)  |   | USEPA - 48         | No                           |
| 4791      | Organic Matter & Sediment Accretion (C.1)  | Accumulation of both mineral and organic matter in wetlands   | USEPA - 47         | No                           |
| 4792      | Drainage (% original wetland drained within 1 km of 1997 boundary)   |   | EC/TNC - 42        | No                           |
| 4793      | Filling (% of 1955 extent that is filled)  |   | EC/TNC - 42        | C.R.(4521)                   |
| 4794      | Land use adjacent to wetland   |   | SOLEC - 28         | C.R.(4521)                   |
| 4795      | Adjacent Land Use  |   | USEPA - 48         | C.R.(4521)                   |
| 4796      | Land-use Characteristics in the Vicinity of Coastal Wetlands   |   | SOLEC - 25         | C.R.(4521)                   |
| 4797      | Changes in land use  |   | EC & partners - 43 | C.R.(4521)                   |
| 4798      | Percent Land Use Classes within Hexagon  |   | USEPA - 48         | No                           |
| 4799      | Land uses and land-use practices, including the nature and extent of riparian vegetation, and information about land use zoning and watershed management plans |   | IJC - 35           | No                           |
| 4800      | Land-use changes, encroachment, development  |   | SOLEC - 28         | C.R.(4521)                   |
| 4801      | Land Use Changes Upstream in the Watersheds of Coastal Wetlands with Inflowing Tributaries   |   | SOLEC - 25         | No                           |
| 4802      | Landscape patterns   |   | EC & partners - 43 | No                           |
| 4803      | Landscape Pattern (broad indicator covered more specifically in next 6 indicators)   | Landscape indicators, calculated from remote sensing, describing the spatial distribution of physical, biological, and cultural features across a geographic area | USEPA - 47         | No                           |
| 4804      | Contagion or Habitat Patchiness  | Land-use and vegetation-cover data to calculate this indicator would be provided by EMAP-characterization   | USEPA - 47         | C.R.(4521)                   |
| 4805      | Landscape Stressors  |   | SOLEC - 24         | C.R.(4521)                   |
| 4806      | Land form and distributary sensitivities; satellite imagery of flooding extent   |   | EC & partners - 43 | No                           |
| 4807      | Encroachment/development basin-wide  |   | SOLEC 94           | No                           |
| 4808      | Land-use Changes, Encroachment/Development Basin-wide  |   | SOLEC - 24         | No                           |
| 4809      | Non-point source urban stormwater best management practices  |   | EC & partners - 43 | No                           |
| 4810      | Roads (length of roadside abutting wetland)  |   | EC/TNC - 42        | C.R.(4521)                   |
| 4811      | Hexagon-wide Road Density  |   | USEPA - 48         | No                           |
| 4812      | Non-point source agricultural best management practices  |   | EC & partners - 43 | No                           |
| 4813      | Restoration of agricultural land to fallow land  |   | EC & partners - 43 | No                           |
| 4814      | Measures of stream-side buffers  |   | EC & partners - 43 | No                           |
| 4815      | Riparian vegetation response modeling  |   | EC & partners - 43 | No                           |
| 4816      | Buffer zones/forestry clear cutting practices - implications for aquatic and riparian communities  |   | EC & partners - 43 | C.R.(4521)                   |
| 4817      | Shoreline Modification (% of shoreline-wetland interface that is modified)   |   | EC/TNC - 42        | C.R.(4521)                   |
| 4818      | Diking (% of total wetland area that is diked)   |   | EC/TNC - 42        | C.R.(4521)                   |



| Ind. code | Indicator name   | Measure                               | Program sponsor    | SOLEC Indicator? |
|-----------|--|---------------------------------------|--------------------|------------------|
| 4819      | Littoral shorelines development  |                                       | EC & partners - 43 | C.R.(4521)       |
| 4820      | Modified shorelines (to provide cover for fish and wildlife)   |                                       | EC & partners - 43 | C.R.(4521)       |
| 4821      | Number of engineering land/water interfaces, such as hardened shorelines, dams, weirs and diversions                                   |                                       | EC & partners - 43 | C.R.(4521)       |
| 4822      | Number and extent of engineered land/ water interfaces, such as hardened shoreline (breakwalls), dams weirs, and diversions            |                                       | IJC - 35           | C.R.(4521)       |
| 4823      | Human-Use (proximity to channel used by motor boats, existing visitor statistic)   |                                       | EC/TNC - 42        | No               |
| 4824      | Recreational Opportunities   |                                       | SOLEC - 25         | No               |
| 4825      | Proximity to Navigable Channels  |                                       | USEPA - 48         | No               |
| 4826      | Proximity to Recreation Boating Activity   |                                       | USEPA - 48         | No               |
| 4827      | Proximity to Navigable Channels and Recreational Boating Activity  |                                       | SOLEC - 25         | No               |
| 4828      | Dredging (distance to nearest)   |                                       | EC/TNC - 42        | No               |
| 4829      | Land-use planning zoning, re-zoning  |                                       | EC & partners - 43 | No               |
| 4830      | Amendment of Official Town Plan (for habitat restoration)  |                                       | EC & partners - 43 | No               |
| 4831      | Number of Employed Persons in Activities Directly or Indirectly Related to Coastal Wetlands  |                                       | SOLEC - 25         | No               |
| 4832      | Quantity/quality of stream base flows  |                                       | EC & partners - 43 | C.R.(4516)       |
| 4833      | Quantity and quality of stream base flow   |                                       | IJC - 35           | C.R.(4516)       |
| 4834      | Sediment Supply and Transport (local expertise rating relative levels at each site)  |                                       | EC/TNC - 42        | C.R.(4516)       |
| 4835      | Sediment Supply Characteristics  |                                       | SOLEC - 25         | C.R.(4516)       |
| 4836      | Streamflow/sedimentation (avoid destructive land-water linkages)   |                                       | EC & partners - 43 | C.R.(4516)       |
| 4837      | Accessible stream length   |                                       | EC & partners - 43 | No               |
| 4838      | Hydrologic Connectivity  |                                       | USEPA - 48         | No               |
| 4839      | Hydrologic Connectivity with the Lake as Determined by the Presence of Dike Structures or Continuous Natural Barriers                  |                                       | USEPA - 48         | No               |
| 4840      | Annual Mean Water Level (from nearest station / level at time of fieldwork)  |                                       | USEPA - 48         | C.R.(4518)       |
| 4841      | Water Level Regulation (years since regulated)   |                                       | EC/TNC - 42        | C.R.(4518)       |
| 4842      | Hydroperiod  | Number of days of inundation per year | USEPA - 47         | No               |
| 4843      | Water level fluctuation  |                                       | SOLEC - 28         | C.R.(4518)       |
| 4844      | Water-level Monitoring   |                                       | SOLEC - 25         | C.R.(4518)       |
| 4845      | Flooding and Dewatering of Wetland   |                                       | SOLEC - 24         | No               |
| 4846      | Monitor representative flow discharge, depth and velocity  |                                       | EC & partners - 43 | No               |
| 4847      | Model flow discharge, depth and velocity   |                                       | EC & partners - 43 | No               |
| 4848      | Ice and Storms (local knowledge to rate conditions at each site)   |                                       | EC/TNC - 42        | C.R.(4519, 4858) |
| 4849      | Climate change (water depth/from nearest climate station their annual trend indicator for temperature compared to historical standard) |                                       | EC/TNC - 42        | C.R.(4857, 4858) |

| Ind. code | Indicator name  | Measure   | Program sponsor                        | SOLEC Indicator?       |
|-----------|---|---|--|------------------------|
| 4850      | Protection from erosive forces  |   | SOLEC - 28                             | No                     |
| 4851      | Protection from Erosive Forces  |   | SOLEC - 24                             | No                     |
| 4852      | Changes in the Status of Protective Barriers such as Sand Spits or Barrier Beaches  |   | SOLEC - 25                             | No                     |
| 4853      | Incidents of spills, accidents, releases relating to use and transport of human controlled and human synthesized products |   | EC & partners - 43                     | No                     |
| 4854      | Water Quality: Chlorides Flowing Into Coastal Wetlands  | Average concentration of chlorides in all existing monitoring sites just upstream of coastal wetlands   |  | No                     |
| 4855      | Water Quality: Nitrates Into Coastal Wetlands   | Concentration of nitrate in all existing monitoring sites just upstream of coastal wetlands. Add average atmospheric loading using LRTAP monitoring?  |  | C.R.(4860)             |
| 4856      | Water Quality: Total Phosphorus Flowing Into Coastal Wetlands   | Concentration of Total Phosphorus in all existing monitoring sites just upstream of coastal wetlands.   |  | C.R.(4860)             |
| 4857      | Global Warming: First Emergence of Water Lilies in Coastal Wetlands   | The number of days after January 1 of first sighting of white on a water lily blossom.  |  | Candidate              |
| 4858      | Global Warming: Ice Duration on the Great Lakes   | Maximum percentage of Great Lakes area covered by ice each year.  |  | Candidate              |
| 4859      | Reproductive output of mink   | Measure DNA of mink tissue and scats collected in spring and fall.  |  | No                     |
| 4860      | Nitrates and Total Phosphorus Into Coastal Wetlands   | Concentration of nitrate and total phosphorus just upstream from, or in a set of, Great Lakes coastal wetlands.   |  | Candidate              |
| 4861      | Water Level Fluctuations  | For each lake: 1) Mean lake level; 2) Lake-wide annual range in monthly averages; 3) Lake-wide seasonal peak (days after January 1); 4) Lake-wide seasonal minimum (days after September 1); and 5) Elevation Difference between Upper and Lower Emergent Vegetation Extent based on Water Level model. |  | Candidate              |
| 7000      | Urban Density   | Human population per square kilometer of existing and proposed development areas. Total area is adjusted to exclude parks and other designated greenspace.  | SOLEC - 27                             | Yes                    |
| 7001      | Efficient urban density   | Non-residential density   | SOLEC 98                               | C.R.(7000)             |
| 7002      | Land conversion   | Percent change in land use type, including agriculture, urban development, and forest, marsh or other natural cover.  | SOLEC - 27, OMMAH - 63                 | Yes                    |
| 7003      | Non-Agriculture land conversion   | acres of land converted annually  | SOLEC - 27, OMMAH - 63                 | C.R.(7002)             |
| 7004      | Economically viable communities - downtown  | vacant commercial locations   | SOLEC - 27                             | C.R.(7000, 7043)       |
| 7005      | Economically viable communities- rural  | vacant buildings  | SOLEC - 27                             | C.R.(7043)             |
| 7006      | Brownfield Redevelopment  | Total acreage of redeveloped brownfields.   | SOLEC - 27                             | Yes                    |
| 7007      | Resource Use  | Energy/water per capita   | SOLEC - 27, OMMAH - 63                 | C.R.(7056, 7057)       |
| 7008      | Solid waste generation  | tons of waste per capita  | SOLEC - 27, Superior - 14              | C.R.(7007)             |
| 7009      | Water use per capita  | litres per day per capita   | SOLEC - 27, University of Toronto - 59 | C.R.(7007)             |
| 7010      | Wastewater discharge  | litres of wastewater per capita   | SOLEC, Superior LaMP - 14              | C.R.(7007)             |
| 7011      | Pollution Prevention  | # of waste reduction programs   | SOLEC - 27                             | No                     |
| 7012      | Mass Transportation   | Percent of commuters using public transportation.   | SOLEC - 27, OMMAH - 63                 | Yes                    |
| 7013      | Traffic Congestion - cost   | Average commuting cost per capita   | SOLEC - 27                             | C.R.(7012)             |
| 7014      | Mass Transit  | % commuters on public transit   | SOLEC - 27, OMMAH - 63                 | C.R.(7012)             |
| 7015      | Efficient transportation  | % of goods moved by fixed link or water   | SOLEC                                  | C.R.(7012)             |
| 7016      | Health care expenditures  | dollars spent per capita  | SOLEC, University of Toronto - 59      | No                     |
| 7017      | Pollution Levels  | Air index, wastewater and solid waste per capita  | SOLEC - 27, 61                         | C.R.(7058, 7059, 7060) |

| Ind. code | Indicator name                      | Measure  | Program sponsor                           | SOLEC Indicator?      |
|-----------|-------------------------------------|--|---|-----------------------|
| 7018      | Beach closings                      | % days that beaches are closed   | SOLEC - 27, OMMAH - 63                    | C.R.(7017)            |
| 7019      | Environmental land legacies         | # landfills and other sites  | SOLEC - 27, OMMAH - 63                    | C.R.(7006)            |
| 7020      | Water discharge quality             | concentration of contaminants  | SOLEC - 27, OMMAH - 63                    | C.R.(7017)            |
| 7021      | Environmental illness and mortality | % change in mortality and morbidity  | SOLEC - 27                                | No                    |
| 7022      | Fish advisories                     | number of restrictions   | SOLEC - 27                                | C.R.(7017)            |
| 7023      | Outdoor recreation - opportunity    | % developed land available for recreation  | SOLEC - 27                                | C.R.(7042)            |
| 7024      | Outdoor recreation                  | average % hours spent on leisure   | SOLEC - 27                                | C.R.(7042)            |
| 7025      | Crime rate and social fabric        | % change in crimes   | SOLEC - 27                                | C.R.(7042)            |
| 7026      | Traffic accidents                   | % change in accidents  | SOLEC                                     | C.R.(7012, 7042)      |
| 7027      | Loss of Natural Features            | % of land protected, % forest change, status of breeding birds and other endemic species | SOLEC - 27, OMMAH - 63, CMHC - 62         | No                    |
| 7028      | Sustainable Agricultural Practices  | Number of Environmental and Conservation farm plans in place.                            | SOLEC - 27                                | Yes                   |
| 7029      | Non-agriculture land loss           | acres of natural land lost   | SOLEC - 27                                | C.R.(7027)            |
| 7030      | Wildlife loss                       | population losses  | SOLEC - 27                                | C.R.(7027)            |
| 7031      | Forest clearing                     | acres clear cut  | SOLEC - 27, OMMAH - 63                    | C.R.(7027)            |
| 7032      | Forest restoration                  | acres successfully replanted   | SOLEC - 27                                | C.R.(7027)            |
| 7033      | Mineral extraction                  | new acres used for mining  | SOLEC - 27, OMMAH - 63                    | C.R.(7027)            |
| 7034      | Fisheries pressure                  | % of biomass harvested   | SOLEC - 27                                | C.R.(7027)            |
| 7035      | Wildlife pressure                   | % of wildlife stock harvested  | SOLEC - 27                                | C.R.(7027)            |
| 7036      | Land hardening                      | # acres paved or permanently covered   | SOLEC - 27                                | C.R.(7027)            |
| 7037      | Chemical use - agricultural         | Tons pesticide and fertilizer used   | SOLEC - 27                                | C.R.(7017)            |
| 7038      | Chemical use - non-agricultural     | Tons of pesticide and fertilizer use - non-agricultural                                  | SOLEC - 27                                | C.R.(7017)            |
| 7039      | Conservation practices              | number of acres using conservation   | SOLEC - 27                                | C.R.(7028, 7017,7027) |
| 7040      | Contaminated areas                  | acres contaminated by landfills and other sites  | SOLEC - 27                                | C.R.(7027, 7006)      |
| 7041      | Cottage and second home development | # of new second homes  | SOLEC - 27                                | C.R.(7002, 7027)      |
| 7042      | Aesthetics                          | Amount of waste and decay around human activities.                                       | SOLEC, University of Toronto - 59         | Yes                   |
| 7043      | Economic Prosperity                 | Unemployment rates within the Great Lakes basin.   | SOLEC - 22, OMMAH - 63                    | Yes                   |
| 7044      | Public Infrastructure               | Infrastructure and facility investments  | OMMAH - 63                                | C.R.(7043)            |
| 7045      | Cultural Heritage                   | Preservation of cultural heritage resources  | SOLEC, University of Toronto - 59         | C.R.(7042)            |
| 7046      | Population Change                   | Growth or decline in urban or rural areas  | SOLEC - 22, OMMAH - 63, 61                | C.R.(7000, 7042,7043) |
| 7047      | Aboriginal Communities              | Number and extent in the Basin   | Canadian Council of Forest Ministers - 51 | C.R.(7042)            |
| 7048      | Biodiversity                        | Changes in areas of natural/semi-natural habitats  | Canadian Council of Forest Ministers - 51 | C.R.(7027)            |
| 7049      | Beauty/Aesthetics                   | Number of comm. environment improvement schemes  | SOLEC                                     | C.R.(7042)            |
| 7050      | Building Permits                    | Number of permits issued annually  | OMMAH - 63                                | C.R.(7000, 7002)      |
| 7051      | Human Impact                        | Measure of damage or remediation   | Superior LaMP - 14                        | C.R.(7017, 7002,7007) |
| 7052      | Reinvestment of Natural Capital     | Social resources to maintain natural resources   | Superior LaMP - 14                        | C.R.(7043, 7007)      |
| 7053      | Green Planning Process              | Number of municipalities with environmental and resource conservation management plans.  | SOLEC 98                                  | Yes                   |

| Ind. code | Indicator name                       | Measure   | Program sponsor    | SOLEC Indicator? |
|-----------|--------------------------------------|---|--------------------|------------------|
| 7054      | Ground surface hardening             | Percentage of land that is covered by buildings, roads, parking lots and other hardened surfaces.   |                    | No               |
| 7055      | Habitat Adjacent to Coastal Wetlands | Land use within 1 kilometer (km) inland of a representative set of coastal wetlands, measured as a weighted score determined by multiplying the wetland perimeter (km) in each land use by an associated weighting factor and dividing by the total upland perimeter (km) of the wetland. |                    | Yes              |
| 7056      | Water Consumption                    | Water use per capita in the Great Lakes basin   |                    | Yes              |
| 7057      | Energy Consumption                   | Energy use in kilowatt hours per capita   |                    | Yes              |
| 7058      | Ground Level Ozone                   | Total number of days the ground level ozone standard is exceeded on an annual basis in the Great Lakes region.  |                    | C.R.(4176)       |
| 7059      | Wastewater Pollution                 | Loadings of metals, BOD and organic chemicals that are released by municipal sewage treatment plants and industrial direct dischargers, into water courses in the Great Lakes basin.  |                    | Yes              |
| 7060      | Solid Waste Generation               | Amount of solid waste generated per capita (tons and cubic meters).   |                    | Yes              |
| 8000      | Threatened species                   | % of known bird species threatened  | OECD - 54          | No               |
| 8001      | Threatened species                   | % of known mammal species threatened  | OECD - 54          | No               |
| 8002      | Threatened species                   | % of known reptile/amphibian species threatened   | OECD - 54          | No               |
| 8003      | Threatened Species                   | % of vascular plant species threatened  | OECD - 54          | No               |
| 8004      | Protected areas                      | number of sites   | OECD - 54          | No               |
| 8005      | Protected area                       | Total size  | OECD - 54          | No               |
| 8006      | Protected area                       | % of territory  | OECD - 54          | No               |
| 8007      | Protected area                       | Per capita: km <sup>2</sup> /1000 inhabitants   | OECD - 54          | No               |
| 8008      | Key species                          | Presence/abundance of key species   | IJC                | No               |
| 8009      | Habitat types                        | Quantity and quality of habitat types   | IJC                | No               |
| 8010      | Endangered species                   | Number and abundance of endangered species  | IJC                | No               |
| 8011      | Biological community integrity       | Cumulative number and abundance of exotic species   | IJC                | No               |
| 8012      | Contaminant levels                   | Toxic contaminant levels in selected species  | IJC                | No               |
| 8013      | Habitat quality                      | Quantity/quality of habitat for critical food web   | IJC                | No               |
| 8014      | Stream flows                         | Quantity/quality of stream base flow  | IJC                | No               |
| 8015      | Engineered shorelines                | Number/extent of engineered land/water edges  | SOLEC, IJC         | No               |
| 8016      | Riparian vegetation                  | Nature/extent of riparian vegetation  | IJC                | No               |
| 8017      | Land use                             | Land use zoning   | IJC                | No               |
| 8018      | Exotic species                       | Range expansion or reduction of exotic/native spp.  | IJC - Lura         | No               |
| 8019      | Exotic species                       | Establishment of new self-sustaining populations  | IJC - Lura         | No               |
| 8020      | Biological community integrity       | Rates of extinction of species  | IJC - Lura         | No               |
| 8021      | Exotic species                       | Warning/prevention/control programs in place  | IJC - Lura         | No               |
| 8022      | Productivity of selected species     | Productivity of bears, bald eagles  | IJC - Lura         | No               |
| 8023      | Habitat connectedness                | Number of barriers - roads, rail, canals, etc   | IJC - Lura         | No               |
| 8024      | Habitat restoration                  | Acres of habitat type restored  | IJC - Lura         | No               |
| 8025      | Habitat disturbance                  | Quantity/quality of dredged materials   | IJC - Lura         | No               |
| 8026      | Species richness                     | Changes in richness or types of organisms   | IJC - Lura         | No               |
| 8027      | Change in keystone or unique species | Population change of selected species   | IJC - Lura         | No               |
| 8028      | Optimum population density           | % of optimum density for selected species   | IJC - Lura         | No               |
| 8029      | Landscape patterns                   | Changes in patterns of land use in each ecoregion   | Superior LaMP - 14 | No               |
| 8030      | Integrity of biotic communities      | Extent of community stability under stress  | Superior LaMP - 14 | No               |
| 8031      | Significant bird species             | Population density of significant bird species  | EC & partners - 43 | No               |
| 8032      | Density of worms                     | Quantity/species diversity of earthworms  | EC & partners - 43 | No               |
| 8033      | Physical features distribution       | Area or % of physical features  | Ontario LaMP - 13  | No               |
| 8034      | Habitat index                        | Habitat index based on IBI concept  | Ontario LaMP - 13  | No               |
| 8035      | Habitat regulations                  | Number of regulations for habitat protection  | IJC - Lura         | No               |
| 8036      | Sensitive habitats                   | % of sensitive habitats protected   | EC & partners - 43 | No               |
| 8037      | Habitat enhancement                  | Amount of habitat enhancement or remediation  | EC & partners - 43 | No               |

| Ind. code | Indicator name                             | Measure  | Program sponsor                           | SOLEC Indicator? |
|-----------|--|--|---|------------------|
| 8038      | Permanent vegetation plots                 | Changes in composition/health of vegetation        | NRBS Synthesis Report                     | No               |
| 8039      | Colonial waterbirds                        | Number of pairs of colonial waterbirds by species  | EC & partners - 43                        | No               |
| 8040      | Wildlife reproductive potential            | Egg size, clutch or brood size for selected spp    | Ontario LaMP - 13                         | No               |
| 8041      | Wildlife productivity                      | Number/% of young raised to independence           | Ontario LaMP - 13                         | No               |
| 8042      | Wildlife age structure                     | Age structure of selected wildlife populations     | Ontario LaMP - 13                         | No               |
| 8043      | Wildlife contaminants                      | Contaminant levels in robust wildlife species      | Ontario LaMP - 13                         | No               |
| 8044      | Wildlife niches                            | Number and saturation of niches present            | Ontario LaMP - 13                         | No               |
| 8045      | Native/exotic species                      | Number/abundance of native vs exotic species       | Ontario LaMP - 13                         | No               |
| 8046      | Bald eagle recovery                        | Abundance and contamination of bald eagles         | Superior LaMP - 14                        | No               |
| 8047      | Fish-eating birds                          | Contaminant levels in young gulls and cormorants   | Superior LaMP - 14                        | No               |
| 8048      | Ungulate range                             | Proportion of historical range or range shifts     | Superior LaMP - 14                        | No               |
| 8049      | Amphibian populations                      | Status and trends of amphibian populations         | Superior LaMP - 14                        | No               |
| 8050      | Marsh birds                                | Status and trends of marsh bird populations        | Superior LaMP - 14                        | No               |
| 8051      | Mink contamination                         | Contaminant loads in mink carcasses                | Superior LaMP - 14                        | No               |
| 8052      | Neotropical birds                          | Abundance and diversity of neotropical birds       | Superior LaMP - 14                        | No               |
| 8053      | Streamflow/sedimentation                   | Trends in streamflow patterns/sediment discharge   | Superior LaMP - 14                        | No               |
| 8054      | Benthic invertebrates                      | Density/richness of invertebrates in streams/lakes | Superior LaMP - 14                        | No               |
| 8055      | Forest fragmentation                       | % closed-canopy, mean patch size, variability      | Superior LaMP - 14                        | No               |
| 8056      | Accessible stream length                   | Total length or % of streams below first barrier   | Superior LaMP - 14                        | No               |
| 8057      | Forest diversity                           | % forest types/total area and historical extent    | Canadian Council of Forest Ministers - 51 | No               |
| 8058      | Forest diversity                           | % and extent of forest type and age class          | Canadian Council of Forest Ministers - 51 | No               |
| 8059      | Protected forest                           | Area, % and representation in protected areas      | Canadian Council of Forest Ministers - 51 | No               |
| 8060      | Species decline                            | Number of species occupying <50% of full range     | Canadian Council of Forest Ministers - 51 | No               |
| 8061      | Forest conversion                          | Area of forest permanently converted to urban, etc | Canadian Council of Forest Ministers - 51 | No               |
| 8062      | Vegetation structural diversity            | # of habitat types/unit area                       | EPA wetlands                              | No               |
| 8063      | Shape index                                | Perimeter of habitat/perimeter of same area circle | EPA wetlands                              | No               |
| 8064      | Plant community characteristics            | dominance/diversity of indicator/rare/sensitive sp | EPA wetlands                              | No               |
| 8065      | Floristic Quality Assessment               | Natural quality scores based on total species list | Ontario NHIC                              | No               |
| 8066      | BioMAP                                     | Stream benthic invertebrates rated for sensitivity | Ontario MOEE                              | No               |
| 8067      | Retention of shoreline species/communities | Rate of loss of selected species/communities       | SOLEC                                     | No               |

| Ind. code | Indicator name                | Measure  | Program sponsor             | SOLEC Indicator? |
|-----------|-------------------------------|--|-----------------------------|------------------|
| 8068      | Wildlife population viability | Pitcher's thistle, L. Huron tansy, dwarf lake iris | Michigan LaMP - 8           | No               |
| 8069      | Wildlife population viability | Insect biomass by species or guild                 | Michigan LaMP - 8           | No               |
| 8070      | Wildlife population viability | # turtle eggs, dead embryos and deformities        | Michigan LaMP - 8           | No               |
| 8071      | Wildlife population viability | Nest production of eagles, gulls, night herons,    | Michigan LaMP - 8           | No               |
| 8072      | Wildlife population viability | mink # offspring, survival, dead/deformities       | Michigan LaMP - 8           | No               |
| 8073      | Wildlife contaminants         | Concentrations in turtles, fox snake, mink         | Michigan LaMP - 8           | No               |
| 8074      | Wildlife contaminants         | Concentrations in osprey, eagles, cormorant, terns | Michigan LaMP - 8           | No               |
| 8075      | Wildlife stress resistance    | Genetic diversity, disease incidence, in species   | Michigan LaMP - 8           | No               |
| 8076      | Wildlife stress resistance    | Immune function, stress biomarkers in species      | Michigan LaMP - 8           | No               |
| 8077      | Wildlife population viability | Species richness and Berger-Parker                 | Michigan LaMP - 8           | No               |
| 8078      | Wildlife population viability | Shannon and Simpson index                          | Michigan LaMP - 8           | No               |
| 8079      | Wildlife population viability | Amphibian assemblage diversity                     | Michigan LaMP - 8           | No               |
| 8080      | Wildlife population viability | Swink and Wilhelm Native Index for plants          | Michigan LaMP - 8           | No               |
| 8081      | Wildlife population viability | Results from breeding bird surveys                 | Michigan LaMP - 8           | No               |
| 8082      | Habitat distribution          | Area of cropland/pasture, woodland/woodlots        | Ontario LaMP - 13           | No               |
| 8083      | Habitat distribution          | Area of urban/industrial, golf courses             | Ontario LaMP - 13           | No               |
| 8084      | Significant habitat types     | Area of habitats designated by gov'ts or NGOs      | Ontario LaMP - 13           | No               |
| 8085      | Lichen distribution           | # and types of lichen species present              |                             | No               |
| 8086      | Shoreline development         | % of shoreline developed/undeveloped               |                             | No               |
| 8087      | Public access                 | % of shoreline length open to public access        |                             | No               |
| 8088      | Degree of roadlessness        | Total length of roads within 3 km of shore         |                             | No               |
| 8089      | Small watershed quality       | % imperviousness                                   | Jerry Wagner - Ohio DNR     | No               |
| 8090      | Small watershed quality       | # of mature trees per acre                         | Jerry Wagner - Ohio DNR     | No               |
| 8091      | Reptiles/amphibians           | Population trends, species diversity               | DAPCAN                      | No               |
| 8092      | Reptiles/amphibians           | # of species with deformities over 10% population  | DAPCAN                      | No               |
| 8093      | Threatened species            | Species added/removed; up/downgraded               | Pat Collins                 | No               |
| 8094      | Threatened species            | Recovery plans completed/needed                    | Pat Collins                 | No               |
| 8095      | Threatened species            | Species on track to recovery/getting worse         | Pat Collins                 | No               |
| 8096      | Development pressure          | # housing units, hotel rooms built                 |                             | No               |
| 8097      | Development pressure          | Real estate land values                            |                             | No               |
| 8098      | Development pressure          | Population density                                 |                             | No               |
| 8099      | Development pressure          | Trends in #, type of building permits              |                             | No               |
| 8100      | Development pressure          | Lot sizes along lakeshore                          |                             | No               |
| 8101      | Wildlife population viability | Density of deer populations                        |                             | No               |
| 8102      | Forest quality                | % land base in conifer vs aspen                    |                             | No               |
| 8103      | Climate change                | Changes in sand spit patterns on Apostles          |                             | No               |
| 8104      | Special communities health    | Heinz emerald dragonfly                            |                             | No               |
| 8105      | Special communities health    | Eastern hemlock population trends                  |                             | No               |
| 8106      | Special communities health    | Winter wren, veery, prairie warbler, wood pewee    |                             | No               |
| 8107      | Agricultural land use         | Area of farmland within 5, 10 km of shoreline      | Great Lakes Commission - 53 | No               |
| 8108      | Agricultural land use         | Farmland as % of total land                        | Great Lakes Commission - 53 | No               |

| Ind. code | Indicator name  | Measure  | Program sponsor             | SOLEC Indicator? |
|-----------|---|--|-----------------------------|------------------|
| 8109      | Agricultural land use   | % of cropland receiving fertilizer   | Great Lakes Commission - 53 | No               |
| 8110      | Agricultural land use: cropland intensity                     | Cropland as percentage of total land area, and trends over time. An alternative measure is cropland as percentage of total farmland, which is the common practice of the agricultural community. But it is useless in this latter form unless indicator 8111 (farmland intensity) is simultaneously available.           | Great Lakes Commission - 53 | No               |
| 8111      | Agricultural intensity  | Farmland as percentage of total land area, and trends over time.   | Great Lakes Commission – 53 | No               |
| 8112      | Land use cover  | % land cover by land use category  | USEPA                       | No               |
| 8113      | Similarity to climax vegetation                               | Degree of similarity to potential (climax) vegetation  | USEPA                       | No               |
| 8114      | Habitat fragmentation   | The pattern of natural habitat remaining within ecoregions/subsections, as measured by 1) area to perimeter ratio; 2) habitat patch size; and 3) percent intact cover.   | USEPA                       | Yes              |
| 8115      | Riparian integrity  | Extent and distribution of riparian vegetation   | USEPA                       | No               |
| 8116      | Ecosystem diversity   | % composition by forest type   | USEPA                       | No               |
| 8117      | Soil quality/condition  | Soil conditions for forest, rangeland, farmland  | USEPA                       | No               |
| 8118      | Species abundance   | Relative population levels of common species   | USEPA                       | No               |
| 8119      | Species condition   | Tree stand condition - insects, disease  | USEPA                       | No               |
| 8120      | Status of endangered and threatened species                   | Known presence/absence, population levels  | USEPA                       | No               |
| 8121      | Status of unique ecosystems/habitats                          | Presence/absence, condition  | USEPA                       | No               |
| 8122      | Status of vulnerable ecosystems/species                       | presence/absence, condition  | USEPA                       | No               |
| 8123      | Ecosystem services  | Timber, carbon sequestration, recreation   | USEPA                       | No               |
| 8124      | Available resources   | land area available for recreation, hunting, etc   | USEPA                       | No               |
| 8125      | Pollution of terrestrial ecosystems                           | Air pollution, accumulation of toxics  | USEPA                       | No               |
| 8126      | Soil erosion  | Soil erosion potential, rates  | USEPA                       | No               |
| 8127      | Urban sprawl  | Developed lands, nighttime lights  | USEPA                       | No               |
| 8128      | Nearshore threatened species                                  | Number and proportion of nearshore species ranked as G1-G3 or S1-S3 in the Biological Conservation Database.   | SOLEC                       | C.R.(8161)       |
| 8129      | Area, Quality and Protection of Special Lakeshore Communities | Area, quality, and protected status of 12 special lakeshore communities occurring within 1 kilometre of shoreline.   | SOLEC                       | Yes              |
| 8130      | Habitat distribution  | % land cover by habitat type <1km from shore   | SOLEC                       | No               |
| 8131      | Extent of Hardened Shoreline                                  | Kilometres of shoreline that have been hardened through construction of sheet piling, rip rap and other erosion control shore protection structures. (Does not include artificial coastal structures such as jetties, groynes, breakwalls, piers, etc.)  | SOLEC                       | Yes              |
| 8132      | Nearshore Land Use Intensity                                  | Land use types, and associated area, within 1 kilometre (km) of shore. Land use types could include urban residential, commercial, and industrial, non-urban residential, intensive agriculture, extensive agricultural, abandoned agricultural, closed-canopy forest, harvested forest, wetland and other natural area. | SOLEC                       | Yes              |
| 8133      | Lake Level Fluctuations                                       | Range, frequency and seasonal pattern of fluctuations in water levels on each of the Great Lakes.  | SOLEC                       | C.R.(4861)       |
| 8134      | Nearshore Plant and Wildlife Problem Species                  | Type and abundance of plant and wildlife problem species, including white sweet clover, leafy spurge, spotted knapweed, garlic mustard, white-tailed deer, and Brown-headed Cowbird, within 1 kilometre (km) from shore.   | SOLEC                       | Yes              |
| 8135      | Contaminants affecting productivity of bald eagles            | 1) Concentrations of DDT Complex, PCB, PCDD, PCDF and other organic contaminants and mercury and other heavy metals in Bald Eagle eggs, blood, and feathers; 2) number of fledged young produced; and 3) number of developmental deformities.  | IJC                         | Yes              |
| 8136      | Extent and Quality of Nearshore natural land cover            | Percent of natural land cover types within 1 km of the shoreline that meet minimum standards of habitat quality.   | SOLEC                       | Yes              |
| 8137      | Nearshore species diversity and stability                     | The type and number of plant and wildlife species, and vegetation regeneration rates within the nearshore area, defined as the area within 1 kilometer (km) of the shoreline.  | SOLEC                       | Yes              |
| 8138      | Expected diversity  | % of sites with >90% expected diversity/population   | SOLEC                       | No               |

| Ind. code | Indicator name  | Measure   | Program sponsor                  | SOLEC Indicator? |
|-----------|---|---|----------------------------------|------------------|
| 8139      | Community/species plans   | Number of plans that are needed, developed, and implemented to maintain or restore high quality, natural nearshore communities— those within 1 kilometre (km) of the shoreline— and federally/nationally listed endangered, threatened, and vulnerable species.   | SOLEC                            | Yes              |
| 8140      | Financial Resources Allocated to Great Lakes Programs           | The total amount of dollars spent on an annual basis by federal and state/provincial agencies and non-governmental organizations in each of four areas: Great Lakes research, monitoring, restoration, and protection (including within nearshore lands).   | SOLEC                            | Yes              |
| 8141      | Shoreline managed under Integrated Management Plans             | Percent of shoreline managed under an integrated shoreline management plan. An integrated shoreline management plan is one that includes consideration of coastal processes, aquatic habitat, and designates appropriate setbacks, etc. and is incorporated into local planning documents (e.g. a municipal Official Plan).   | SOLEC                            | Yes              |
| 8142      | Stream flow   | Measure of stream flow and suspended sediments at the mouth of major tributaries and connecting channels.   | SOLEC                            | Yes              |
| 8143      | Interior species  | Density of interior forest/grassland species  | SOLEC                            | No               |
| 8144      | Agricultural land use: Key Best Management Practices (BMP)      | There are many BMPs. This indicator should be an aggregate of key desirable practices related to (i) cropping and tilling (conservation- or no-tilling, crop rotation, cover crops, grassed waterways, strip or contour cropping, shelterbelts), (ii) use of farm chemicals and manure (decreased use of pesticides and fertilizer per unit area, integrated pest and nutrient management, etc.). At present, the aggregate indicator will be limited to those practices for which adequate data are available. Others (e.g. integrated pest management) should be included as they become available (e.g. through the census). Measures (good, indifferent, bad) include expert value judgments on how to weight the individual practices in the aggregate, and on what constitutes good or bad. | SOLEC, Great Lakes Commission-53 | C.R.(7028)       |
| 8145      | Forest certification  | Acreage managed under forest certification  | SOLEC                            | No               |
| 8146      | Artificial coastal structures                                   | The number and type of artificial coastal structures (including groynes, breakwalls, riprap, piers, etc) on the Great Lakes shoreline. Artificial coastal structures include structures that extend into shallow waters at an angle from the shoreline, or are placed offshore for the purpose of breaking the force of the waves. They are distinct from the hardened shoreline works described in indicator #8131, Hardened Shoreline, which modify the shoreline edge itself.  | SOLEC                            | Yes              |
| 8147      | Contaminants affecting the American otter                       | 1) Concentrations of heavy metals (e.g., Hg, Pb, Cd) found in hair, blood, liver, and brain of the American otter; and 2) concentrations of DDT and metabolites, PCBs/ PCDFs/PCDDs, Dioxin, and other organic contaminants found in fatty tissues, liver, and blood of the American otter.  | SOLEC                            | Yes              |
| 8148      | Nearshore endemic species                                       | Number, extent and viability of endemic species populations within 1 kilometre of shore.  | New                              | C.R.(8161)       |
| 8149      | Nearshore protected areas                                       | The percentage of the Great Lakes shoreline under various levels of protection in six classes as defined by the International Union for the Conservation of Nature (IUCN). The six IUCN classes are 1) strict protection, such as nature reserves and wilderness; 2) ecosystem conservation and recreation, such as national parks; 3) conservation of natural features, such as natural monuments; 4) conservation through active management, such as wildlife management areas; 5) protected landscapes/seascapes; and 6) managed resource protected areas, such as sustainable use areas.  | SOLEC -                          | Yes              |
| 8150      | Breeding bird Diversity and Abundance                           | Diversity and abundance of breeding bird populations and communities in selected habitat types, and an avian index of biotic integrity.   |                                  | Yes              |
| 8151      | Number, extent and viability of endemic species                 | Number, extent and viability of endemic species populations basin-wide.   | New                              | C.R.(8161)       |
| 8152      | Threatened species  | Number and proportion of Great Lakes basin species ranked as G1-G3 or S1-S3 in the Biological Conservation Database.  | Combined                         | C.R.(8161)       |
| 8153      | Areas of land under formal land management plan (not completed) |   |                                  | No               |



| <b>Ind. code</b> | <b>Indicator name</b>   | <b>Measure</b>   | <b>Program sponsor</b>      | <b>SOLEC Indicator?</b> |
|------------------|---|--|-----------------------------|-------------------------|
| 8160             | Agricultural Land Use: Livestock density                        | Number of livestock per unit area, weighted by amount of manure-nitrogen produced per head.  | Great Lakes Commission – 53 | No                      |
| 8161             | Threatened Species  | Number, extent, and viability of species ranked as G1-G3 or S1-S3 in the Biological Conservation Database.   |                             | Candidate               |
| 9000             | Acid Rain   | 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). |                             | Candidate               |
| 9001             | Atmospheric Visibility: Prevention of Significant Deterioration | Percentage of daylight hours per year which have <10 km Visible Range (for relative humidity values < 80% and no observed weather codes from synoptic observations).   |                             | Candidate               |

## Appendix 3 — Relevancies

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

- C Indicator Type. Based on the State-Pressure-Human Activity model, each SOLEC 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.
- C Environmental Compartments. This category sorts the SOLEC 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.
- C Issues. Environmental management decisions often reflect an attempt to address an issue rather than a medium or geographic location. Specific issues that SOLEC indicators support include toxic contaminants (29), nutrients (12), exotic species (8), habitat (28), climate change (4), and stewardship (11).
- C GLWQA Annexes. Several of the annexes of the GLWQA include monitoring and reporting requirements. The proposed SOLEC 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.
- C GLWQA Beneficial Use Impairments. Under Annex 2 of the GLWQA, fourteen Beneficial Use Impairments are listed for consideration by Lakewide Management Plans and Remedial Action Plans. The SOLEC indicators address to some extent 11 of the 14 listed use impairments.
- C IJC Desired Outcomes. The IJC listed nine Desired Outcomes in its report *Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement* (1996). SOLEC 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.
- C 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.

To facilitate cross referencing of the SOLEC indicators to the alternate categories, a section has been added to each indicator description (Appendix 1) that lists all the applicable categories. This matrix of alternate groupings of SOLEC indicators is also being incorporated into the SOLEC indicators database. Users will be able to retrieve the list of indicators associated with any of the sorting categories.

While the SOLEC 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 SOLEC 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 SOLEC indicators. **Suggestions and comments on the relevance of the SOLEC indicators to these or other alternate categories are encouraged.**

Table on following pages.

| ID#  | Indicator name  | Indicator Type |          |                | Environmental Compartments |       |      |           |       |      |        |        | Issues    |         |         |                |             |             | SOLEC groupings  |                  |                       |          |              |          | GLWQA Annex |                   |                   |              |                 |                    |                       |  |  |  |  |
|------|---|----------------|----------|----------------|----------------------------|-------|------|-----------|-------|------|--------|--------|-----------|---------|---------|----------------|-------------|-------------|------------------|------------------|-----------------------|----------|--------------|----------|-------------|-------------------|-------------------|--------------|-----------------|--------------------|-----------------------|--|--|--|--|
|      |   | State          | Pressure | Human Activity | Air                        | Water | Land | Sediments | Biota | Fish | Humans | Toxics | Nutrients | Exotics | Habitat | Climate Change | Stewardship | Open Waters | Nearshore Waters | Coastal Wetlands | Nearshore Terrestrial | Land Use | Human Health | Societal | Unbounded   | 1 Spec Objectives | 2 LaMPs RAPS BUIs | 3 Phosphorus | 4 Oil - Vessels | 5 Wastes - Vessels | 6 Shipping/ Pollution |  |  |  |  |
|      |   |                |          |                |                            |       |      |           |       |      |        |        |           |         |         |                |             |             |                  |                  |                       |          |              |          |             |                   |                   |              |                 |                    |                       |  |  |  |  |
| 6    | Aquatic Habitat   | x              |          |                |                            | x     |      |           |       |      |        |        |           | x       |         |                |             | x           | x                | x                |                       |          |              |          |             |                   | x                 |              |                 |                    |                       |  |  |  |  |
| 8    | Salmon and trout  | x              |          |                |                            |       |      |           | x     |      | x      | x      | x         | x       |         |                |             | x           | x                |                  |                       |          |              |          |             |                   | x                 |              |                 |                    |                       |  |  |  |  |
| 9    | Walleye and <i>Hexagenia</i>                                      | x              |          |                |                            |       |      |           | x     | x    | x      | x      |           |         |         |                |             | x           | x                |                  |                       |          |              |          |             |                   | x                 |              |                 |                    |                       |  |  |  |  |
| 17   | Preyfish Populations  | x              |          |                |                            |       |      |           | 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 ( <i>Diaporeia hoyi</i> )                     | x              |          |                |                            |       |      |           | x     | x    | x      | x      | x         |         |         |                |             | x           |                  |                  |                       |          |              |          |             |                   | x                 |              |                 |                    |                       |  |  |  |  |
| 101  | Deformities, Erosion, Lesions and Tumors in Nearshore Fish        | x              |          |                |                            |       |      |           | x     |      | x      |        |           |         |         |                |             | x           | x                |                  |                       |          |              |          |             |                   | x                 |              |                 |                    |                       |  |  |  |  |
| 104  | Benthos Diversity and Abundance                                   | x              |          |                |                            |       |      |           | x     |      | x      | x      |           | x       |         |                |             | x           | x                |                  |                       |          |              |          |             |                   | x                 |              |                 |                    |                       |  |  |  |  |
| 109  | Phytoplankton Populations   | x              |          |                |                            |       |      |           | x     |      | x      | x      |           |         |         |                |             | x           | x                |                  |                       |          |              |          |             |                   | x                 |              |                 |                    |                       |  |  |  |  |
| 111  | Phosphorus Concentrations and Loadings                            |                | x        |                |                            | x     |      |           |       |      |        | x      |           |         |         |                |             | x           | x                | x                |                       |          |              |          |             |                   | x                 | x            | x               |                    |                       |  |  |  |  |
| 113  | Contaminants in Recreational Fish                                 |                | x        |                |                            |       |      |           | x     |      | x      |        |           |         |         |                |             | x           | x                |                  |                       |          |              |          |             |                   | x                 | x            |                 |                    |                       |  |  |  |  |
| 114  | Contaminants In Young-of-the-Year Spottail Shiners                |                | x        |                |                            |       |      |           | x     |      | x      |        |           |         |         |                |             |             | x                |                  |                       |          |              |          |             |                   | x                 |              |                 |                    |                       |  |  |  |  |
| 115  | Contaminants in Colonial Nesting Waterbirds                       |                | x        |                |                            |       |      |           | x     |      | x      |        |           |         |         |                |             | x           | x                |                  |                       |          |              |          |             |                   | x                 | x            |                 |                    |                       |  |  |  |  |
| 116  | Zooplankton Populations as Indicators of Ecosystem Health         | x              |          |                |                            |       |      |           | 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           |                  |                  |                       |          |              |          |             |                   | x                 |              |                 |                    |                       |  |  |  |  |
| 119  | Concentrations of Contaminants in Sediments Cores                 |                | x        |                |                            |       |      |           | x     |      | x      |        |           |         |         |                |             | x           |                  |                  |                       |          |              |          |             |                   |                   |              |                 |                    |                       |  |  |  |  |
| 120  | Contaminant Exchanges Between: Air to Water and Water to Sediment |                | x        |                |                            | 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                |                  |                       |          |              |          |             |                   | 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     |      | x      |        |           |         |         |                |             |             |                  |                  |                       |          |              |          |             |                   |                   |              |                 |                    |                       |  |  |  |  |
| 4175 | Drinking Water Quality  |                | x        |                |                            | x     |      |           |       |      | x      | x      |           |         |         |                |             |             | x                |                  |                       |          |              |          |             |                   | x                 | x            |                 |                    |                       |  |  |  |  |
| 4176 | Air Quality   |                | x        |                |                            | x     |      |           |       |      | x      |        |           |         |         |                |             |             |                  |                  |                       |          |              |          |             |                   | x                 |              |                 |                    |                       |  |  |  |  |
| 4177 | Chemical Contaminants in Human Tissue                             |                | x        |                |                            |       |      |           | x     |      | x      |        |           |         |         |                |             |             |                  |                  |                       |          |              |          |             |                   |                   |              |                 |                    |                       |  |  |  |  |
| 4178 | Radionuclides   |                | x        |                |                            | x     | x    |           |       |      | x      |        |           |         |         |                |             |             |                  |                  |                       |          |              |          |             |                   |                   |              |                 |                    |                       |  |  |  |  |

| GLWQA Annex (con't) |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        | IJC Desired Outcomes |                |                       |         |      |       |          |          |                   | GLFC Objectives |             |          |                      |           | Beneficial Use Impairments |                  |                  |                   |               |                       |                 |                |        |    |    |    |  |  | Totals |
|---------------------|--------------|--------------------|-----------------------|---------------|---------------------|----------------------|------------------|----------------|----------------|------------------|---------------|----------------|----------------|------------------|----------------------|------------------------|----------------------|----------------|-----------------------|---------|------|-------|----------|----------|-------------------|-----------------|-------------|----------|----------------------|-----------|----------------------------|------------------|------------------|-------------------|---------------|-----------------------|-----------------|----------------|--------|----|----|----|--|--|--------|
| 7 Dredging          | 8 Facilities | 9 Contingency Plan | 10 Hazard. Poll. List | 11 Monitoring | 12 Pers. Toxic Subs | 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 | 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- | 14 F&W Habitat | Totals |    |    |    |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        |                      | x              |                       | x       | x    | x     | x        |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                | x      | 16 |    |    |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        |                      |                |                       | x       | x    | x     | x        |          |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    | 16 |    |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        |                      |                |                       | x       | x    | x     |          |          |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    | 16 |    |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        |                      |                |                       | x       | x    | x     | x        | x        |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    | 17 |    |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        |                      |                |                       | x       | x    | x     | x        | x        |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    | 14 |    |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        |                      |                |                       |         |      |       |          |          |                   |                 |             | x        |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 9  |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 8  |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        |                      |                |                       | x       | x    | x     | x        | x        |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    | 18 |    |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                |                  |               |                |                |                  |                      |                        | x                    |                |                       |         |      |       |          |          |                   |                 |             | x        |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    | 10 |    |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        |                      |                |                       |         |      |       |          |          |                   |                 |             | x        |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 11 |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        | x                    |                |                       |         |      | x     |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 | x              |        |    | 11 |    |  |  |        |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  | x                    |                        | x                    |                |                       |         | x    |       |          |          |                   |                 |             | x        |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 15 |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                |                  | x             |                |                | x                | x                    | x                      |                      |                |                       | x       | x    | x     | x        | x        | x                 |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    | 19 |    |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                |                  |               |                |                |                  | x                    | x                      |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 9  |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                |                  |               |                |                |                  | x                    | x                      |                      |                |                       |         | x    |       |          |          |                   |                 |             | x        |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 14 |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 | x              |        |    |    | 9  |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  | x              |                | x                |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 10 |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 8  |  |  |        |
|                     |              |                    |                       | x             | x                   |                      | x                |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 8  |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  | x              |                | x                |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 12 |  |  |        |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 4  |  |  |        |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 4  |  |  |        |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 4  |  |  |        |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 4  |  |  |        |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 4  |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               | x              |                | x                |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    | 12 |    |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                |                  | x             |                |                | x                |                      |                        | x                    |                |                       |         |      |       |          |          |                   | x               |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 19 |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                | x                |               |                |                | x                |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 8  |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                | x              |                  |               |                | x              | x                |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 15 |  |  |        |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                | x                |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 8  |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                | x                |               |                |                | x                |                      |                        | x                    |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 10 |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                | x                |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    |    | 9  |  |  |        |



| GLWQA Annex (con't) |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        | IJC Desired Outcomes |                |                       |         |      |       |          |          |                   | GLFC Objectives |             |          |                      |           | Beneficial Use Impairments |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  | Totals |  |  |  |  |   |    |    |   |    |    |    |
|---------------------|--------------|--------------------|-----------------------|---------------|---------------------|----------------------|------------------|----------------|----------------|------------------|---------------|----------------|----------------|------------------|----------------------|------------------------|----------------------|----------------|-----------------------|---------|------|-------|----------|----------|-------------------|-----------------|-------------|----------|----------------------|-----------|----------------------------|------------------|------------------|-------------------|---------------|-----------------------|-----------------|----------------|--------|--|--|--|--|--|--------|--|--|--|--|---|----|----|---|----|----|----|
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|                     |              |                    |                       |               |                     |                      |                  |                | x              |                  |               |                | x              |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  | 5 |    |    |   |    |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    | 10 |   |    |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   | x               |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   | 10 |    |   |    |    |    |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                | x                |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   | 10 |    |   |    |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   | x               |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   | 9  |    |   |    |    |    |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   | x               |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   | 9  |    |   |    |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   | x               |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   | 10 |    |   |    |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   | x               |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    | 12 |   |    |    |    |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    | 6  |   |    |    |    |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    | 5  |   |    |    |    |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    | 6 |    |    |    |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        | x                    |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    | 8 |    |    |    |
|                     |              |                    |                       | x             |                     |                      |                  |                |                | x                |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    | 9 |    |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   | 6  |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    | 6 |    |    |    |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   | 4  |    |    |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   | 3  |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    | 6 |    |    |    |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    | 7 |    |    |    |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    | 3 |    |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   | 2  |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   | 11 |    |    |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    | 5 |    |    |    |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    | 5 |    |    |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   | 8  |    |    |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      | x                      |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   | 5  |    |    |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   |    | 3  |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   |    | 9  |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   |    | 10 |    |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   |    | 11 |    |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |  |  |  |  |  |        |  |  |  |  |   |    |    |   |    |    | 10 |



| ID#  | Indicator name  | Indicator Type |          |                | Environmental Compartments |       |      |           |       |      |        |        |           | Issues  |         |                |             |             |                  | SOLEC groupings  |                       |          |              |          |           |                |                   |              |                 | GLWQA Annex        |                       |   |   |   |   |   |   |  |
|------|---|----------------|----------|----------------|----------------------------|-------|------|-----------|-------|------|--------|--------|-----------|---------|---------|----------------|-------------|-------------|------------------|------------------|-----------------------|----------|--------------|----------|-----------|----------------|-------------------|--------------|-----------------|--------------------|-----------------------|---|---|---|---|---|---|--|
|      |   | State          | Pressure | Human Activity | Air                        | Water | Land | Sediments | Biota | Fish | Humans | Toxics | Nutrients | Exotics | Habitat | Climate Change | Stewardship | Open Waters | Nearshore Waters | Coastal Wetlands | Nearshore Terrestrial | Land Use | Human Health | Societal | Unbounded | 1 Spec Objects | 2 LaMPs RAPs BUIs | 3 Phosphorus | 4 Oil - Vessels | 5 Wastes - Vessels | 6 Shipping/ Pollution |   |   |   |   |   |   |  |
| 8135 | Contaminants Affecting Productivity of Bald Eagles              |                | x        |                |                            |       |      |           | x     |      |        | x      |           |         |         |                | x           | x           |                  | x                |                       |          |              |          |           |                |                   | x            |                 |                    |                       |   |   |   |   |   |   |  |
| 8136 | Extent and Quality of Nearshore Natural Land Cover              | x              |          |                |                            |       | x    |           |       |      |        |        |           | x       |         |                |             |             | x                |                  |                       |          |              |          |           |                | x                 |              |                 |                    |                       |   |   |   |   |   |   |  |
| 8137 | Nearshore Species Diversity and Stability                       | x              |          |                |                            |       |      |           | x     |      |        |        | x         | x       |         |                |             |             |                  | x                |                       |          |              |          |           |                | x                 |              |                 |                    |                       |   |   |   |   |   |   |  |
| 8139 | Community / Species Plans                                       |                | x        |                |                            |       |      |           | x     |      |        |        |           |         | x       |                |             |             | x                |                  |                       | x        |              |          |           |                |                   |              |                 |                    |                       |   |   |   |   |   |   |  |
| 8140 | Financial Resources Allocated to Great Lakes Programs           |                |          | x              |                            |       |      |           |       | x    |        |        |           |         |         | x              |             |             |                  | x                |                       |          | x            |          |           |                |                   |              |                 |                    |                       |   |   |   |   |   |   |  |
| 8141 | Shoreline Managed Under Integrated Management Plans             |                |          | x              |                            |       | x    |           |       | x    |        |        |           |         |         | x              |             |             | x                | x                |                       | x        |              |          |           |                |                   |              |                 |                    |                       |   |   |   |   |   |   |  |
| 8142 | Streamflow  |                | x        |                |                            | x     |      | x         |       |      |        |        |           | x       |         |                |             | x           | x                | x                |                       |          |              |          |           | x              | x                 | x            |                 |                    |                       |   |   |   |   |   |   |  |
| 8146 | Artificial Coastal Structures                                   |                | x        |                |                            |       | x    |           |       |      |        |        |           | x       |         |                |             |             |                  | x                |                       |          |              |          |           |                | x                 |              |                 |                    |                       |   |   |   |   |   |   |  |
| 8147 | Contaminants Affecting the American Otter                       |                | x        |                |                            |       |      |           | x     |      |        | x      |           |         |         |                |             |             |                  | x                | x                     |          |              |          |           |                | x                 | x            |                 |                    |                       |   |   |   |   |   |   |  |
| 8149 | Nearshore Protected Areas                                       |                |          | x              |                            |       | x    |           |       |      |        |        |           | x       |         |                |             |             |                  | x                |                       |          |              |          |           |                |                   |              |                 |                    |                       |   |   |   |   |   |   |  |
| 8150 | Breeding Bird Diversity and Abundance                           | x              |          |                |                            |       |      |           | x     |      |        |        |           |         |         |                |             |             |                  |                  |                       |          | x            |          |           |                | x                 |              |                 |                    |                       |   |   |   |   |   |   |  |
| 8161 | Threatened Species  | x              |          |                |                            |       |      |           | x     | x    |        |        |           | x       | x       |                |             | x           | x                | x                | x                     |          |              |          |           |                |                   |              |                 |                    |                       |   |   |   |   |   |   |  |
| 9000 | Acid Rain   |                | x        |                |                            | x     |      |           |       |      |        | x      |           |         |         |                |             |             |                  |                  |                       |          |              | x        |           | x              |                   |              |                 |                    |                       |   |   |   |   |   |   |  |
| 9001 | Atmospheric Visibility: Prevention of Significant Deterioration | x              |          |                |                            | x     |      |           |       |      |        |        |           |         |         |                |             |             |                  |                  |                       |          |              | x        |           |                |                   |              |                 |                    |                       |   |   |   |   |   |   |  |
| 80   | COUNT   | 28             | 37       | 15             | 6                          | 14    | 14   | 4         | 21    | 13   | 14     | 29     | 12        | 8       | 28      | 4              | 11          | 22          | 25               | 21               | 17                    | 11       | 8            | 13       | 6         | 18             | 39                | 3            | 0               | 0                  | 0                     | 0 | 0 | 0 | 0 | 0 | 0 |  |

| GLWQA Annex (con't) |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        | IJC Desired Outcomes |                |                       |         |      |       |          |          |                   | GLFC Objectives |             |          |                      |           | Beneficial Use Impairments |                  |                  |                   |               |                       |                 |                |        |    |    |  |  |  | Totals |
|---------------------|--------------|--------------------|-----------------------|---------------|---------------------|----------------------|------------------|----------------|----------------|------------------|---------------|----------------|----------------|------------------|----------------------|------------------------|----------------------|----------------|-----------------------|---------|------|-------|----------|----------|-------------------|-----------------|-------------|----------|----------------------|-----------|----------------------------|------------------|------------------|-------------------|---------------|-----------------------|-----------------|----------------|--------|----|----|--|--|--|--------|
| 7 Dredging          | 8 Facilities | 9 Contingency Plan | 10 Hazard. Poll. List | 11 Monitoring | 12 Pers. Toxic Subs | 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 | 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- | 14 F&W Habitat | Totals |    |    |  |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                | x                |               |                |                |                  | x                    | x                      |                      |                |                       |         |      |       |          |          |                   | x               |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | 14 |    |  |  |  |        |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  | x                    |                        |                      | x              |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | x  | 10 |  |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        |                      |                |                       |         |      |       |          |          |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | 9  |    |  |  |  |        |
|                     |              |                    |                       | x             |                     | x                    |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | 7  |    |  |  |  |        |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | 5  |    |  |  |  |        |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | 7  |    |  |  |  |        |
|                     |              |                    |                       | x             | x                   | x                    |                  |                |                | x                |               |                |                |                  |                      |                        |                      | x              |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            | x                |                  |                   |               |                       |                 |                | x      | 17 |    |  |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      | x              |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                | x      | 8  |    |  |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  |                |                | x                |               |                |                |                  | x                    | x                      |                      |                |                       |         |      |       |          |          |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | 14 |    |  |  |  |        |
|                     |              |                    |                       |               |                     |                      |                  |                |                |                  |               |                |                |                  |                      |                        |                      | x              |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | 5  |    |  |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                |                  |               |                |                |                  | x                    |                        |                      |                |                       |         |      |       |          |          |                   |                 | x           |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | 7  |    |  |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  |                |                | x                |               |                |                |                  | x                    |                        |                      |                |                       |         |      |       |          |          |                   | x               |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | x  | 15 |  |  |  |        |
|                     |              |                    |                       | x             | x                   |                      |                  | x              |                | x                |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        | x  | 10 |  |  |  |        |
|                     |              |                    |                       | x             |                     |                      |                  | x              |                |                  |               |                |                |                  |                      |                        |                      |                |                       |         |      |       |          |          |                   |                 |             |          |                      |           |                            |                  |                  |                   |               |                       |                 |                |        |    | 5  |  |  |  |        |
| 0                   | 0            | 0                  | 0                     | 60            | 19                  | 20                   | 1                | 4              | 1              | 14               | 2             | 1              | 1              | 9                | 4                    | 26                     | 15                   | 3              | 26                    | 8       | 9    | 8     | 7        | 7        | 2                 | 0               | 17          | 1        | 4                    | 4         | 0                          | 3                | 1                | 1                 | 1             | 0                     | 2               | 13             |        |    |    |  |  |  |        |

## Appendix 4 — Criteria

### A-4.1 SOLEC 98 Indicator Project Goals, Objectives and Criteria

**Project Goals:** The aim of the SOLEC 98 indicators project is to gather together a list of indicators that will be used by the Parties (to the GLWQA) to report on the health of the Great Lakes basin ecosystem on a regular basis (ie. yearly, biennially, every five years...). In most cases, these indicators have already been developed by various groups, commissions, or agencies. The goal of this project is to gather the indicators that will be most useful basin-wide and understandable to the interested public (including educators, media, and decision-makers) while remaining scientifically valid.

**Project Objectives:** To present indicators that represent portions of the Great Lakes ecosystem but show the state of and trends (improving, deteriorating or neutral trends) of a larger ecosystem component so that, used all together, the health of the system can be assessed.

**Criteria:** The following criteria have been adapted from a recent EPA document, *Process for Selecting Environmental Indicators and Supporting Data*, modified slightly to better fit this project. The three main criteria discussed at length with the SOLEC 98 Steering Committee and the Indicator Group are: 1) are the indicators **necessary** to determine the overall health of the Great Lakes; 2) are the indicators **sufficient** to determine the overall health of the Great Lakes; and 3) are the indicators **feasible** (economically and in terms of human resources) to use in determining the health of the Great Lakes ecosystem? Additional criteria useful for selecting SOLEC indicators are also included.

| Criterion                | Explanation   | Rating* |
|--------------------------|---|---------|
| <b>Validity</b>          |   |         |
| Relevance                | Does the indicator present information relevant to Great Lakes ecosystem integrity?   |         |
| Appropriate Scale        | Does the indicator respond to changes on appropriate geographic (ie. lakewide, basin-wide) and temporal (ie. monthly or yearly) scales for SOLEC reporting?                               |         |
| Accurate                 | Does the indicator accurately reflect the ecosystem component it is intended to represent?  |         |
| Sensitive                | Is the indicator appropriately sensitive, i.e., are changes in the indicator highly correlated with changing trends in the information it is selected to represent?                       |         |
| Discriminating           | Can the indicator distinguish natural variability from human-induced changes?   |         |
| <b>Understandability</b> |   |         |
| Understandable           | Is the indicator appropriate for decision-makers and the general public? Is the level of information from the indicator appropriate for environmental managers to use in decision making? |         |
| Simplicity               | Is the indicator simple and direct?   |         |

| Criterion                                | Explanation  | Rating* |
|--|--|---------|
| Presentation                             | Can the indicator be presented in a format tailored to environmental managers?   |         |
| Documented                               | Is the methodology used to create the indicator well-documented and understandable so that it can be easily communicated and reproduced?                           |         |
| <b>Interpretability</b>                  |  |         |
| Interpretable                            | Is there a reference condition or benchmark for the indicator against which current status and trends can be compared?   |         |
| Trend Evaluation                         | Will data that have been collected over a sufficient period of time allow analysis of trends?  |         |
| <b>Information Richness</b>              |  |         |
| Richness                                 | Does the indicator represent multiple ecosystem components or stressors?   |         |
| Broad Application                        | Is the indicator broadly applicable to many geographic areas?  |         |
| <b>Data Availability</b>                 |  |         |
| Currently existing                       | Are adequate data available for immediate indicator use?   |         |
| Easily Available                         | Are data easily available? Can they be retrieved with a minimum of fuss?   |         |
| Long term record                         | Do data currently exist to allow for analysis of environmental trends?   |         |
| <b>Timeliness</b>                        |  |         |
| Timely                                   | Are changes in the environment reflected quickly by the indicator?   |         |
| Anticipatory                             | Does the indicator provide early warning of changes?   |         |
| <b>Cost Considerations (Feasibility)</b> |  |         |
| Ease of Quantification                   | Does the indicator reflect a feature of the environment that can be quantified simply, using standard methodologies with a known degree of accuracy and precision? |         |
| Data collection                          | Can data supporting the indicator be obtained with reasonable cost and effort by some Great Lakes organization?  |         |
| Calculation and Interpretation           | Can calculations and interpretations for the indicator be obtained with reasonable cost and effort?  |         |

\* The rating system used during the development of the Indicator List presented at SOLEC 98 (Version 2) was left to the discretion of the Core Groups: some opted to use a simple Yes or No system while a few used a more complex number rating system. See Section A-4.2 for post-SOLEC 98 indicator rating exercise.

### Criteria for the whole SOLEC Indicator List:

Are each of these indicators in combination **necessary** to assess the overall health of the Great Lakes ecosystem?

Are these indicators in combination **sufficient** to assess the overall health of the Great Lakes ecosystem?

## A-4.2 Post-SOLEC 98 Criteria Rating

After SOLEC 98, the Indicator Group agreed that an independent, third-party assessment of the SOLEC indicators against the 21 criteria (presented in Section A-4.1) would be a useful exercise. It was felt that an evaluation of the degree to which each indicator met the criteria would help validate the proposed indicators that rated high, and would point out those that needed further development work, refinement or even possible removal from the list. The criteria rating could also play a role in prioritizing the indicators for future work. The assessment took place after the majority of revisions had been made to the SOLEC indicators, based on comments and concerns heard at SOLEC 98 and shortly afterwards.

***The results presented are preliminary. They represent a summary of the assessment by an independent contractor who is familiar with the description of each indicator, but they have not been endorsed by the SOLEC Indicator Group.***

### **Rating Process**

The rating process was based on the 21 criteria from seven different categories presented in the previous section, A-4.1. For SOLEC purposes, some of the categories of criteria can be considered more important than others. For example, at this stage of the indicator development process, it is more important that an indicator is relevant to Great Lakes ecosystem integrity than it is for an indicator to have an existing source of supporting data. To capture the varying importance of the criteria, each of the seven overall criteria categories were assigned a weight based on importance.

| <b>Criteria Category</b>             | <b>Weight</b> |
|--------------------------------------|---------------|
| Validity                             | 3             |
| Understandability                    | 3             |
| Interpretability                     | 3             |
| Information Richness                 | 2             |
| Data Availability                    | 2             |
| Timeliness                           | 1             |
| Cost Considerations<br>(Feasibility) | 1             |

A rather elaborate scheme was invented to provide an overall numeric score for each indicator based on subjective ratings of each of the 21 criteria and the weighting of the 7 criteria groupings. Every indicator was rated on how well it met each of the criteria using a scale of 1 to 3: 1 = does not meet criteria, 2 = partially meets criteria, 3 = fully meets criteria. The assessments were based on the indicator descriptions as written, and in some cases there was insufficient information given to rate a criterion high. Whenever possible, the benefit of the doubt was given to the indicator if the required information could be inferred from the description.

The scores within each category were summed and weighted. The weighted scores were then summed across categories to obtain a total overall score for the indicator. Because this system gave the appearance of much greater precision to the category and the overall scores than was warranted, an index was created by further adjusting the numerical ratings to a 5 point scale and rounding to the nearest whole number. Descriptive rankings were then assigned as follows: 5 = Excellent, 4 = Good, 3 = Moderate, 2 = Fair, 1 = Poor.

Seventy-five of the 80 SOLEC indicators were ranked, and the results are presented in the table that follows. The five indicators from the Societal group were not ranked because they have not been revised since SOLEC 98. Of the 75 ranked indicators, 9 ranked Excellent, 56 ranked Good, and 10 ranked Moderate. Closer inspection by the Core groups of the individual criterion ratings should reveal those aspects of the indicators or the indicator descriptions that could be improved, if possible, to affect a higher rating.

| ID # | Indicator Name  | Validity | Understandability | Interpretability | Information Richness | Data Availability | Timeliness | Feasibility | Ranking   |
|------|---|----------|-------------------|------------------|----------------------|-------------------|------------|-------------|-----------|
| 17   | Preyfish Populations  | E        | E                 | G                | E                    | E                 | M          | G           | Excellent |
| 111  | Phosphorus Concentrations and Loadings                                | G        | E                 | E                | E                    | G                 | E          | E           | Excellent |
| 115  | Contaminants in Colonial Nesting Waterbirds                           | E        | E                 | E                | E                    | E                 | M          | E           | Excellent |
| 4081 | Coliform Levels of Nearshore Recreational Waters                      | E        | E                 | E                | E                    | M                 | M          | E           | Excellent |
| 4176 | Air Quality   | E        | E                 | E                | E                    | E                 | G          | E           | Excellent |
| 4516 | Sediment Flowing into Coastal Wetlands                                | G        | E                 | E                | E                    | G                 | G          | E           | Excellent |
| 7059 | Wastewater Pollution  | G        | E                 | E                | E                    | G                 | M          | E           | Excellent |
| 8135 | Contaminants Affecting Productivity of Bald Eagles                    | E        | E                 | E                | G                    | G                 | M          | G           | Excellent |
| 9000 | Acid Rain   | G        | E                 | E                | E                    | E                 | M          | E           | Excellent |
| 8    | Salmon and Trout  | G        | G                 | E                | M                    | G                 | F          | G           | Good      |
| 9    | Walleye and Hexagenia   | G        | G                 | E                | G                    | G                 | M          | M           | Good      |
| 18   | Sea Lamprey   | E        | E                 | E                | E                    | F                 | G          | M           | Good      |
| 68   | Native Unionid Mussels  | G        | E                 | E                | G                    | F                 | F          | M           | Good      |
| 72   | Fish Entrainment  | E        | G                 | M                | M                    | G                 | E          | G           | Good      |
| 93   | Lake Trout and Scud ( <i>Diaporeia hoyi</i> )                         | E        | E                 | E                | E                    | M                 | M          | G           | Good      |
| 101  | Deformities, Erosion, Lesions and Tumors in Nearshore Fish            | E        | E                 | E                | E                    | F                 | G          | F           | Good      |
| 104  | Benthos Diversity and Abundance                                       | G        | E                 | E                | E                    | F                 | F          | G           | Good      |
| 109  | Phytoplankton Populations   | E        | G                 | M                | E                    | F                 | G          | F           | Good      |
| 113  | Contaminants in Recreational Fish                                     | E        | E                 | M                | G                    | G                 | G          | G           | Good      |
| 114  | Contaminants in Young-of-the-Year Spottail Shiners                    | G        | E                 | M                | E                    | G                 | E          | G           | Good      |
| 116  | Zooplankton Populations   | G        | E                 | G                | E                    | M                 | G          | G           | Good      |
| 117  | Atmospheric Depositions of Toxic Chemicals                            | G        | G                 | E                | E                    | F                 | M          | M           | Good      |
| 118  | Toxic Chemical Concentrations in Offshore Waters                      | E        | E                 | E                | E                    | F                 | E          | G           | Good      |
| 119  | Concentration of Contaminants in Sediment Cores                       | E        | E                 | E                | E                    | F                 | M          | G           | Good      |
| 4083 | Chemical Contaminants in Fish Tissue                                  | G        | E                 | M                | E                    | M                 | F          | G           | Good      |
| 4088 | Chemical Contaminant Intake from Air, Water, Soil and Food            | G        | M                 | E                | E                    | F                 | F          | M           | Good      |
| 4175 | Chemical and Microbial Drinking Water Quality                         | G        | E                 | E                | E                    | G                 | M          | G           | Good      |
| 4177 | Chemical Contaminants in Human Tissue                                 | G        | G                 | E                | E                    | F                 | F          | M           | Good      |
| 4178 | Radionuclides   | G        | E                 | G                | E                    | G                 | M          | F           | Good      |
| 4179 | Geographic Patterns and Trends in Disease Incidence                   | G        | E                 | M                | G                    | G                 | M          | G           | Good      |
| 4501 | Invertebrate Community Health   | G        | E                 | E                | E                    | F                 | M          | G           | Good      |
| 4502 | Fish Community Health   | G        | E                 | E                | E                    | F                 | M          | M           | Good      |
| 4503 | Deformities/Eroded Fins/Lesions/Tumors (DELT) in Coastal Wetland Fish | G        | E                 | E                | E                    | F                 | M          | E           | Good      |
| 4504 | Amphibian Diversity and Abundance                                     | G        | E                 | E                | G                    | G                 | F          | G           | Good      |
| 4506 | Contaminants in Snapping Turtle Eggs                                  | G        | E                 | E                | E                    | F                 | F          | F           | Good      |
| 4507 | Wetland-Dependent Bird Diversity and Abundance                        | G        | E                 | E                | G                    | G                 | M          | G           | Good      |
| 4510 | Wetland Area by Type  | G        | E                 | E                | M                    | F                 | F          | M           | Good      |

| ID # | Indicator Name   | Validity | Understandability | Interpretability | Information Richness | Data Availability | Timeliness | Feasibility | Ranking  |
|------|--|----------|-------------------|------------------|----------------------|-------------------|------------|-------------|----------|
| 4513 | Presence, Abundance & Expansion of Invasive Plants                         | E        | E                 | E                | G                    | F                 | E          | M           | Good     |
| 4519 | Global Warming: Number of Extreme Storms                                   | G        | M                 | G                | M                    | G                 | M          | G           | Good     |
| 4857 | Global Warming: First Emergence of Water Lily Blossoms in Coastal Wetlands | G        | E                 | E                | M                    | M                 | M          | F           | Good     |
| 4858 | Global Warming: Ice Duration on the Great Lakes                            | G        | E                 | E                | M                    | G                 | F          | G           | Good     |
| 4860 | Nitrates and Total Phosphorus Into Coastal Wetlands                        | E        | E                 | E                | E                    | F                 | E          | G           | Good     |
| 4861 | Water Level Fluctuations   | G        | E                 | E                | M                    | E                 | G          | G           | Good     |
| 7000 | Urban Density  | E        | G                 | M                | E                    | F                 | M          | F           | Good     |
| 7012 | Mass Transportation  | G        | G                 | E                | G                    | F                 | F          | F           | Good     |
| 7043 | Economic Prosperity  | E        | G                 | M                | G                    | E                 | M          | E           | Good     |
| 7055 | Habitat Adjacent to Coastal Wetlands                                       | G        | G                 | G                | G                    | F                 | M          | F           | Good     |
| 7056 | Water Consumption  | G        | E                 | M                | G                    | G                 | F          | E           | Good     |
| 7057 | Energy Consumption   | E        | E                 | M                | E                    | G                 | M          | E           | Good     |
| 7060 | Solid Waste Generation   | G        | E                 | G                | E                    | G                 | M          | F           | Good     |
| 8114 | Habitat Fragmentation  | E        | E                 | E                | E                    | F                 | G          | M           | Good     |
| 8129 | Area, Quality, and Protection of Special Lakeshore Communities             | G        | E                 | E                | E                    | M                 | F          | F           | Good     |
| 8131 | Extent of Hardened Shoreline   | G        | E                 | E                | G                    | M                 | F          | M           | Good     |
| 8132 | Nearshore Land Use Intensity   | G        | E                 | E                | E                    | F                 | M          | M           | Good     |
| 8134 | Nearshore Plant and Wildlife Problem Species                               | G        | G                 | E                | E                    | F                 | F          | F           | Good     |
| 8136 | Extent and Quality of Nearshore Natural Land Cover                         | G        | E                 | E                | E                    | G                 | F          | M           | Good     |
| 8139 | Community/Species Plans  | M        | E                 | G                | E                    | E                 | F          | G           | Good     |
| 8141 | Shoreline Managed Under Integrated Management Plans                        | M        | E                 | E                | G                    | F                 | F          | G           | Good     |
| 8142 | Streamflow   | G        | E                 | E                | E                    | F                 | G          | G           | Good     |
| 8146 | Artificial Coastal Structures  | E        | E                 | E                | G                    | F                 | M          | M           | Good     |
| 8147 | Contaminants Affecting the American Otter                                  | E        | E                 | E                | G                    | M                 | M          | M           | Good     |
| 8149 | Protected Nearshore Areas  | G        | G                 | E                | E                    | M                 | F          | M           | Good     |
| 8150 | Breeding Bird Diversity and Abundance                                      | G        | E                 | E                | G                    | M                 | G          | M           | Good     |
| 8161 | Threatened Species   | G        | E                 | E                | E                    | G                 | E          | M           | Good     |
| 9001 | Atmospheric Visibility: Prevention of Significant Deterioration            | G        | G                 | M                | E                    | G                 | M          | G           | Good     |
| 6    | Aquatic Habitat  | G        | M                 | M                | E                    | F                 | M          | F           | Moderate |
| 120  | Contaminant Exchanges Between Media: Air to Water, and Water to Sediment   | G        | F                 | G                | E                    | F                 | M          | M           | Moderate |
| 4511 | Gain in Restored Wetland Area by Type                                      | M        | E                 | G                | M                    | F                 | F          | M           | Moderate |
| 7002 | Land Conversion  | G        | G                 | M                | M                    | F                 | M          | M           | Moderate |
| 7006 | Brownfield Redevelopment   | G        | G                 | M                | F                    | M                 | F          | M           | Moderate |
| 7028 | Sustainable Agricultural Practices   | G        | E                 | M                | G                    | F                 | F          | G           | Moderate |
| 7042 | Aesthetics   | G        | M                 | M                | G                    | F                 | M          | F           | Moderate |
| 7053 | Green Planning Process   | M        | E                 | M                | G                    | F                 | F          | M           | Moderate |



| ID # | Indicator Name  | Validity | Understandability | Interpretability | Information Richness | Data Availability | Timeliness | Feasibility | Ranking  |
|------|---|----------|-------------------|------------------|----------------------|-------------------|------------|-------------|----------|
| 8137 | Nearshore Species Diversity and Stability             | M        | E                 | G                | E                    | P                 | F          | F           | Moderate |
| 8140 | Financial Resources Allocated to Great Lakes Programs | M        | G                 | E                | M                    | F                 | F          | M           | Moderate |

## Appendix 5 — SOLEC Indicator Database

This appendix provides details of the fields and features of the SOLEC Indicator Database (described briefly in Section 3.4 of this report).

### Database Features - Things it can do

The database was designed primarily to assist the SOLEC Indicator Group organize and sort the hundreds of indicators that were identified for the Great Lakes. Fields were incorporated to provide descriptive information about each indicator, e.g., its title, the specific measurement to be taken, the ecosystem objectives that it supports, the purpose for the indicator, its desired endpoint or some other reference value, its features and limitations, an illustration, information to help interpret the indicator, and any additional comments. Taken together, this information provides a basis for a review of the proposed indicator against the SOLEC criteria, and a rationale for indicator selection for the SOLEC list.

Additional fields in the database were designed to hold information useful for sorting the indicators and tracking their progress through the process of SOLEC indicator selection. Included is information about the original source for each indicator (by Great Lakes program and/or reference document), indicator type, applicability to SOLEC categories, applicability to a number of alternative groupings (e.g., IJC Desired Outcomes), data availability, and whether the indicator had been modified or selected for the SOLEC list. Further details of the database fields and the information they contain are presented in the Database Fields section below.

All of the information about a selected indicator can be viewed on screen. A user can therefore select any given indicator, identify to which groupings it is applicable, obtain full descriptive information, and determine if a current data source has been identified.

To make the database useful to others besides the Indicator Group, additional capabilities have been added. A user has the ability to filter the indicators by a number of criteria. By entering a key word or phrase, a user can search through the Title, Measure and Purpose fields for indicators that contain the key word. For example, a search on “contamin” will return a list of all the proposed indicators that mention contaminant, contaminants, contaminate, contaminates, contamination, contaminating, etc. All the indicators in the database can be included, or the search can be restricted to only those proposed as SOLEC indicators.

Sorting is also possible for the proposed SOLEC indicators according to a number of alternative groupings, in addition to the SOLEC categories. Groupings have been provided for indicator type (state, pressure or human activity), environmental compartments, Great Lakes issues, GLWQA Annexes, GLWQA Beneficial Use Impairments, IJC Desired Outcomes, and Great Lakes Fishery Commission Objectives.

Reporting capabilities are also being incorporated into the database and will be available with the online version. Users will be able to select pre-formatted reports based on results of the sorting criteria, from simple lists of indicator titles to full page indicator descriptions. User-specified reports for selected fields in the database will also be possible.

## Database Fields - Information stored about each indicator

The following are descriptions of the fields and the information they contain in the SOLEC indicator database. Not all information is available for all the indicators in the database. The most complete entries are provided for the proposed SOLEC indicators.

### The Indicator “Description” Information

**Name of Indicator.** What is a brief, descriptive title for the indicator? Example: *Contaminants in Top Predator Fish*

**Measure.** What is really being measured? Example: *PCB congeners in 6 year old lake trout*

**Ecosystem Objective.** What environmental goals or objectives does the indicator address or support? Example: *Lake Superior LaMP Human Health Objective, “Fish and wildlife . . . should be safe to eat”*

**Purpose of the Indicator.** What is the larger category of interest? An indicator is a surrogate for something more consequential than the indicator, *per se*. Does the indicator provide information about the environment or human health, about a stressor (contaminants, habitat, exotic species, etc.), about sources of the stressors (industrial discharge, wetland diking, etc.), or about human activities (or responses such as laws, volunteer programs, etc.). Example: *A direct measure of the level of organic contaminants in the food chain and an indirect measure of potential harm to human health through consumption of contaminated fish.*

**Endpoint.** (Or range, outcome or other reference value) What is the frame of reference to interpret the indicator? Example: *FDA Action Limit = 2.0 ug/g PCB in fish tissue.*

**Features of the Indicator.** As applicable, describe space and/or time scales represented by the indicator, anticipated variability, linkages with other indicators, and/or other information to help determine or document the viability of this indicator to be included on the SOLEC list. Example: *Measurement of the concentration of PCBs in whole lake trout has been part of an annual program for over 20 years. To reduce variability in the analytical results and to increase the ability to track trends in the levels of contaminants over time, fish from the same age/size are collected each year from designated locations in each lake, and they are composited for analysis . . . .*

**Illustration.** What will be displayed graphically? How will the display incorporate the desired endpoint or reference value? Example: *For each lake, a graph will be displayed showing the annual mean concentration and 95% confidence intervals of total PCBs in lake trout composites. The data series from 1972 to the present will be included. Reference concentrations will be marked on the figure for comparison to the measured values.*

**Limitations of the Indicator.** How costly are the data to collect at the recommended frequency? What issues may compromise the utility of the indicator? How closely linked is the indicator to the broader issue being assessed? Example: *This is a relatively costly indicator that requires much coordination and collaboration between federal, state and provincial agencies. The indicator, however, is very closely linked to the overall abundance of mobile PCBs in the Great Lakes ecosystem. The indicator is an integrator of the level of PCBs in the*

*food web over large areas of each lake over several years, therefore it cannot be effectively associated with specific sources.*

**Indicator Interpretation.** Is other information needed to place this indicator in context? On what basis can the subjective tags of “good” and “poor” be applied to the state of the environment or to progress toward the ecosystem objective being supported by the indicator? Example: *Variations in feeding habits or food web structures could affect annual results and complicate interpretations of long-term trends. Measurements of PCBs (particulate and dissolved) in the water column would help distinguish food web influences from changes in the environmental concentrations of PCBs. A scale from, say 50 ppm (worse than found in 1972) to 0.05 ppm (the proposed health protection value, even though it is for fillets and not whole fish) could be used to apply subjective assessments to the degree to which the ecosystem is free from PCBs: 50 ppm = totally unacceptable, 5 ppm = poor, 0.5 ppm = fair and 0.05 ppm = good.*

**Comments.** Provide any other information that would assist the process of indicator selection or the application of the indicator. Is a particular methodology required? Are special calculations needed to derive or interpret the indicator? Is additional work needed to define the indicator? Is the indicator feasible? Example: *To maintain compatibility with the historic, long-term data, established protocols for fish collection, sample preparation and analysis must be followed. This indicator has been in use in the Great Lakes basin for over 20 years. It is directly related to Great Lakes objectives, widely accepted, easily understood, and the supporting data are of high quality.*

## **The Indicator “Sorting” Information**

**Indicator Name.** This field is copied from the “description” section above.

**Measure.** This field is copied from the “description” section above.

**Program Source and Document.** What program or group previously proposed the indicator? What document did it come from? Major sources of proposed Great Lakes indicators included the Lakewide Management Plans, IJC, Great Lakes Fishery Commission, and previous SOLEC background documents.

**Indicator Type.** For which element of the State-Pressure-Human Activities (Response) (SPR) framework does the indicator provide information?

**Applicable SOLEC Indicator Category.** Previous SOLEC presentations and reports were organized around a few major ecosystem components and human interactions. To be consistent with, and extend these foundations, the indicators can be grouped accordingly. The categories include: Open and Nearshore Waters, Coastal Wetlands, Nearshore Terrestrial, Land Use, Human Health and Societal.

**Applicable to other programs or groups.** The SOLEC Indicator Group has made an initial judgement concerning the applicability of each indicator to other programs or useful groupings. Current groupings have been provided for environmental compartments (e.g., air, water, land, biota), Great Lakes issues (e.g., toxics, nutrients, exotics), GLWQA Annexes, GLWQA Beneficial Use Impairments, IJC Desired Outcomes, and Great Lakes Fishery Commission Objectives.

**Applicable Lake or Lake Basin.** What is the broad, geographic applicability for the indicator? The majority of indicators will be applicable across the whole basin, however, some indicators may vary between lakes or lake basins.

**Status as SOLEC indicator?** The database has been useful to help organize and sort indicators, but not every indicator will be nominated to the SOLEC List. Therefore, a field containing the status of each indicator was included in the database. “*Candidate*” applies to those indicators under consideration for the SOLEC List. “*Yes*” applies to those which are proposed to be included in the SOLEC list. “*No*” applies to those not proposed for the SOLEC list, even though they may be useful in another context. “*Concept Retained*” applies to those which contain one or more features that were combined, merged, or altered and that exist in another, related indicator (with the new indicator number in brackets—i.e. Concept Retained (7008) means that a feature of this particular indicator exists in indicator number 7008).

**Data Availability.** Recent data that directly support the indicator would greatly improve an illustration of the indicator and would provide a means to immediately report on the ecosystem component being measured. Three aspects to indicator data are retained in the database: *Data Availability* (Yes, No, Unknown), *Data Quality* (Excellent, Good, Fair, Poor, Unknown), and *Data Source and Comments* (Where are the data? Is a time series available? What other information is available about the data?).

## Appendix 6 — Definitions and Acronyms

The definitions presented below were intended to help guide SOLEC 98 and encourage consistent use of terminology in order to achieve agreement on assessing the state of various components of the Great Lakes and measuring progress toward the purpose of the Great Lakes Water Quality Agreement (i.e., to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem).

| TERM      | DEFINITION   | EXAMPLE   | REFERENCE   |
|-----------|--|---|---|
| VISION    | A general description of the desired state of a lake, geographical area, or bioregion that is expressed by a group of stakeholders. A vision statement provides a description of desired state — it provides direction and establishes a horizon to be sought.   | The Grand Traverse Bay Watershed Initiative has established the following vision statement:<br><i>“The ecological integrity of the Grand Traverse Bay watershed will be sustained or restored to ensure regional economic viability and quality use by future generations.”</i>   | Grand Traverse Bay Watershed Initiative, 1102 Cass Street, Suite B, Traverse City, Michigan 49684; 616-935-1514   |
| GOAL      | A condition or state desired to be brought about through a course of action or program. They are usually qualitative statements that provide direction for plans and projects. Goals are not specific numerical limitations, but conditions or states which can be obtained through careful planning and implementation. | The water use goal for the fishery, established by the Hamilton Harbour Stakeholder Group, is <i>“that water quality and fish habitat should be improved to permit an edible, naturally-reproducing fishery for warmwater species, and water and habitat conditions in Hamilton Harbour should not limit natural reproduction and the edibility of cold water species.”</i>   | Hamilton Harbour Remedial Action Plan Writing Team. 1992. RAP for Hamilton Harbour. Goals, options, and recommendations. Volume 2, Main Report. Stage II Remedial Action Plan. Burlington, Ontario, 329 pp. |
| OBJECTIVE | Specific descriptions of the state or condition that must be met in order to achieve goals and the vision.   | In Hamilton Harbour on western Lake Ontario, an objective is to shift from a fish community indicative of a eutrophic environment, such as white perch ( <i>Morone americana</i> ), alewife ( <i>Alosa pseudoharengus</i> ), bullheads ( <i>Ictalurus</i> spp.), and carp ( <i>Cyprinus carpio</i> ), to a self-sustaining community more representative of a mesotrophic environment, containing northern pike ( <i>Esox lucius</i> ), bass ( <i>Micropterus salmoides</i> and <i>M. dolomieu</i> ), yellow perch ( <i>Perca flavescens</i> ), and sunfish ( <i>Lepomis</i> spp.). | Hamilton Harbour Remedial Action Plan Writing Team. 1992. RAP for Hamilton Harbour. Goals, options, and recommendations. Volume 2, Main Report. Stage II Remedial Action Plan. Burlington, Ontario, 329 pp. |

| TERM                    | DEFINITION  | EXAMPLE  | REFERENCE   |
|-------------------------|---|--|---|
| INDICATOR               | The Organization for Economic Cooperation and Development defines indicator as “a parameter, or a value derived from parameters, which points to, provides information about, or describes the state of a phenomenon / environment / area, with a significance extending beyond that directly associated with a parameter value.” In the context of the Great Lakes, it is a measurable feature or features that provide outcome-oriented, managerially and scientifically useful, evidence of environmental and ecosystem quality or reliable evidence of trends in quality. | Typically, there is a spectrum of outcome-oriented parameters which are monitored and collectively serve as an indicator. For example, parameters which collectively serve as an indicator for the fishery objective for Hamilton Harbour include: abundance of key species; sustainability of indigenous populations; presence of non-indigenous species; and rate of habitat loss and preservation.  | Environment Canada and U.S. Environmental Protection Agency. 1995. State of the Great Lakes . Toronto, Ontario, Chicago, Illinois, 56 pp.   |
| PARAMETER or DATA POINT | A single measurable feature which provides information regarding the status and trend associated with that feature and can be combined with other parametric measurements to serve as an indicator.   | Examples of parameters or data points which can collectively serve as indicators for the Hamilton Harbour fishery objective include quantitative measurements of populations of different species, population trends, amount and quality of littoral habitat, etc.   | Hamilton Harbour Remedial Action Plan Writing Team. 1992. RAP for Hamilton Harbour. Goals, options, and recommendations. Volume 2, Main Report. Stage II Remedial Action Plan. Burlington, Ontario, 329 pp. |
| TARGET                  | Specific, attainable, quantitative, end points for indicators that determine achievement of objectives.   | Fishery targets for Hamilton Harbour include:<br>* total biomass of fish in littoral habitats - 200-250 kg/ha;<br>* total biomass of native piscivores (e.g., northern pike, largemouth bass) - 20-25%;<br>* percent of native species - 80-90%;<br>* species richness - 6-7 species per survey transect;<br>* piscivore biomass in littoral habitats - 40-60 kg/ha;<br>* specialist (e.g., yellow perch, pumpkinseed - <u>Lepomis gibbosus</u> , alewife) biomass in littoral habitats - 70-100 kg/ha; and<br>* generalist (e.g., carp and bullheads) biomass in littoral habitats - 30-90 kg/ha. | R.G. Randall and V.W. Cairns, Department of Fisheries and Oceans, 867 Lakeshore Road Burlington, Ontario L7R 4A6 Canada   |

## Acronyms

AOC - Areas of Concern  
BIA - Biodiversity Investment Area  
BOD - Biological Oxygen Demand  
BUI - Beneficial Use Impairment  
DELT - Deformities, erosion, lesions and tumors  
FCGO - Fish Community Goals and Objectives  
FFG - Functional Feeding Groups  
GIS - geographic information system  
GLFC - Great Lakes Fishery Commission  
GLWQA - Great Lakes Water Quality Agreement  
IBI - Index of Biotic Integrity  
IJC - International Joint Commission  
IUCN - International Union for the Conservation of Nature  
LaMP - Lakewide Management Plan  
MMP - Marsh Monitoring Program  
NOAA - National Oceanic and Atmospheric Administration  
NOAEL - No observed adverse effect level  
PBT - Persistent, Bioaccumulative, and Toxic Chemicals  
RAP - Remedial Action Plan  
SOLEC - State of the Lakes Ecosystem Conference



## Appendix 7 — Documents

The following table lists most of the documents and reports used by the Indicator Group to extract indicators and other information. Please go to the end of the table for a list of the acronyms used here.

| Ref. No. | Program Sponsor | Document Information   | Core Group(s) |    |    |    |    |    |   |
|----------|-----------------|--|---------------|----|----|----|----|----|---|
|          |                 |  | OW            | NW | CW | NT | HH | LU | S |
| 1        | GLFC            | Busiahn, T.R. (ed) 1990. <i>Fish-Community Objectives for Lake Superior</i> . Great Lakes Fishery Commission Special Publication 90-1. 23 pp.  | X             | X  |    |    |    |    |   |
| 2        | GLFC            | Eshenroder, R.L. et al. 1995. <i>Fish-Community Objectives for Lake Michigan</i> . Great Lakes Fishery Commission Special Publication 95-3. 56 pp.   | X             | X  |    |    |    |    |   |
| 3        | GLFC            | Kerr, S. J. and G.C. Le Tendre. 1991. <i>The State of the Lake Ontario Fish Community in 1989</i> . Great Lakes Fishery Commission Special Publication 91-3. 38 pp.                                    |               | X  |    |    |    |    |   |
| 4        | GLFC            | Lake Erie Committee. 1997. <i>Lake Erie: Fish Community Goals and Objectives</i> . 34 pp.  |               | X  |    |    |    |    |   |
| 5        | GLFC            | DesJardine, R.L. et al. 1995. <i>Fish-community objectives for Lake Huron</i> . Great Lakes Fishery Commission Special Publication 95-1. 38 pp.  |               | X  |    |    |    |    |   |
| 7        | GLFC            | Great Lake Fishery Commission. 1995. <i>Habitat Advisory Board Meeting # 95-2, Minutes with Attachments</i> . 410 pp.  |               | X  |    |    |    |    |   |
| 8        | Michigan LaMP   | Esparza et al. 1996. <i>Lake Michigan Indicators: Degradation of Wildlife Population/Bird or Animal Deformities - Population Viability (draft)</i> . 6 pp.   |               |    | X  | X  |    |    |   |
| 9        | Michigan LaMP   | Esparza et al. 1996. <i>Matrix for Aquatics/Habitat Indicators for Lake Michigan</i> . 6 pp.   | X             | X  | X  |    |    |    |   |
| 11       | Ontario LaMP    | Lake Ontario Pelagic Community Health Indicators Committee (LOPCHIC). 1993. <i>Lake Ontario: An Ecosystem in Transition</i> . 65 pp.   | X             | X  |    |    |    |    |   |
| 12       | Ontario LaMP    | Lake Ontario Ecosystem Objectives Working Group. 1992. <i>Progress Report of the Ecosystem Objectives Working Group on Ecosystem Objectives and Environmental Indicators for Lake Ontario</i> . 61 pp. | X             | X  |    |    |    |    | X |
| 13       | Ontario LaMP    | Lake Ontario Ecosystem Objectives Working Group. 1993. <i>Indicators of Progress Toward Lake Ontario Ecosystem Objectives</i> . 6 pp.  |               |    |    | X  |    |    |   |
| 14       | Superior LaMP   | Lake Superior Work Group and Lake Superior Binational Forum. 1996. <i>Ecosystem Principles and Objectives, Indicators and Targets for Lake Superior</i> .  |               |    |    | X  | X  | X  | X |
| 16       | SOLEC           | De Vault, D. et al. 1995. <i>Toxic Contaminants in the Great Lakes</i> . Background paper. State of the Lakes Ecosystem Conference 1994. 37 pp.  | X             |    |    |    |    |    |   |
| 17       | SOLEC           | Manno, J. et al. 1995. <i>Effects of Great Lakes Basin Contaminants on Human Health</i> . Background paper. State of the Lakes Ecosystem Conference 1994. 83 pp.                                       |               |    |    |    | X  |    |   |
| 18       | SOLEC           | Koonce, J.F. 1995. <i>Aquatic Community Health of the Great Lakes</i> . Background paper. State of the Lakes Ecosystem Conference 1994. 37 pp.   | X             |    |    |    |    |    |   |

| Ref. No. | Program Sponsor | Document Information  | Core Group(s) |    |    |    |    |    |   |  |
|----------|-----------------|---|---------------|----|----|----|----|----|---|--|
|          |                 |   | OW            | NW | CW | NT | HH | LU | S |  |
| 19       | SOLEC           | Dodge, D. and R. Kavetsky. 1995. <i>Aquatic Habitat and Wetlands of the Great Lakes</i> . Background paper. State of the Lakes Ecosystem Conference 1994. 70 pp.                        | X             |    | X  |    |    |    |   |  |
| 20       | SOLEC           | Allardice, D.R. and S. Thorp. 1995. <i>A Changing Great Lakes Economy: Economic and Environmental Linkages</i> . Background paper. State of the Lakes Ecosystem Conference 1994. 45 pp. |               |    |    |    |    |    | X |  |
| 21       | SOLEC           | Neilson, M. et al. 1995. <i>Nutrients: Trends and System Response</i> . Background paper. State of the Lakes Ecosystem Conference 1994. 20 pp.  | X             | X  |    |    |    |    |   |  |
| 22       | SOLEC           | United States/Canada. 1995. <i>State of the Great Lakes 1995</i> . 56 pp.   |               | X  | X  |    |    |    |   |  |
| 23       | SOLEC           | Reid, R. and K. Holland. 1997. <i>The Land by the Lakes: Nearshore Terrestrial Ecosystems</i> . Background paper. State of the Lakes Ecosystem Conference 1996. 142 pp.                 |               |    |    |    | X  |    |   |  |
| 24       | SOLEC           | Leger, W. and R. Greenwood. 1997. <i>Information and Information Management</i> . Background paper. State of the Lakes Ecosystem Conference 1996. 96 pp.                                |               |    | X  |    |    |    |   |  |
| 25       | SOLEC           | Maynard, L. and D. Wilcox. 1997. <i>Coastal Wetlands</i> . Background paper. State of the Lakes Ecosystem Conference 1996.  |               |    | X  |    |    |    |   |  |
| 26       | SOLEC           | Edsall, T.A. and M.N. Charlton. 1997. <i>Nearshore Waters of the Great Lakes</i> . Background paper. State of the Lakes Ecosystem Conference 1996. 152 pp.                              |               | X  |    |    |    |    |   |  |
| 27       | SOLEC           | Thorp, S., R. Rivers, and V. Pebbles. 1997. <i>Impacts of Changing Land Use</i> . Background paper. State of the Lakes Ecosystem Conference 1996. 118 pp.                               |               |    | X  |    |    |    | X |  |
| 28       | SOLEC           | United States/Canada. 1997. <i>State of the Great Lakes 1997</i> . 76 pp.   |               | X  | X  | X  |    |    |   |  |
|          | SOLEC           | Fuller, K. and H. Shear. 1996. <i>Integration Paper</i> . State of the Lakes Ecosystem Conference 1996. 65 pp.  |               |    |    |    | X  |    |   |  |
| 29       | IJC             | Ryder, R.A. and C.J. Edwards. 1985. A Conceptual Approach for the Application of Biological Indicators of Ecosystem Quality in the Great Lakes Basin. 167 pp.                           |               | X  |    | X  |    |    |   |  |
| 30       | IJC             | IJC Ecosystems Objectives Committee. 1990. <i>Final Report of the Ecosystem Objectives Committee</i> . 53 pp.   |               | X  |    |    |    |    |   |  |
| 31       | IJC             | Edwards, C.J. and R.A. Ryder (eds). 1990. Biological Surrogates of Mesotrophic Ecosystem Health in the Laurentian Great Lakes. 69 pp.   | X             | X  |    |    |    |    |   |  |
| 33       | IJC             | Seidl, P.J. (ed). 1993. <i>Toward a State of the Great Lakes Basin Ecosystem Report</i> . State of the Great Lakes Basin Ecosystem Task Force. 162 pp.                                  | X             |    |    |    |    |    |   |  |
| 35       | IJC             | IJC. 1996. <i>Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement</i> . 82 pp.  |               | X  | X  | X  |    |    |   |  |
| 36       | IJC             | Fox (ed). 1994. <i>Bioindicators as a Measure of Success for Virtual Elimination of Persistent Toxic Substances</i> . 37 pp.  |               | X  | X  | X  |    |    |   |  |
| 38       | EC              | Campbell, M., D. Spear, and V. MacLaren. 1996. <i>Measuring Up: A Resource Guide for Municipal State of the Environment Reporting</i> . 70 pp.  | X             |    |    |    |    |    |   |  |
| 39       | EC              | Environment Canada Indicators Task Force. 1991. <i>A Report on Canada's Progress Towards a National Set of Environmental Indicators</i> . SOE Report 91-1. 98 pp.                       |               | X  |    |    |    |    |   |  |
| 40       | EC/CMHC/ICURR   | MacLaren, V.W. 1996. <i>Developing Indicators of Urban Sustainability: A focus on the Canadian Experience</i> . 147 pp.   |               |    |    |    |    |    | X |  |

| Ref. No. | Program Sponsor    | Document Information  | Core Group(s) |    |    |    |    |    |   |   |
|----------|--------------------|---|---------------|----|----|----|----|----|---|---|
|          |                    |   | OW            | NW | CW | NT | HH | LU | S |   |
| 41       | EC/GLFC/USEPA      | Hartig, J. 1993. <i>A Survey of Fish-community and Habitat Goals/Objectives/Targets and Status in Great Lakes Areas of Concern</i> . 95 pp.   |               | X  |    |    |    |    |   |   |
| 42       | EC/NNC             | Snell, E. 1997. <i>Great Lakes Biomonitoring Project: Initial Development of a Framework for Monitoring Priority Coastal Marsh Health and Integrity</i> . 70 pp.  |               |    | X  | X  |    |    |   |   |
| 43       | EC                 | Environment Canada et al. 1997. <i>A Compendium of Ecosystem Health Goals, Objectives and Indicators (Prototype)</i> . 132 pp.  |               |    | X  | X  |    |    |   | X |
| 45       | USEPA              | USEPA. 1998. <i>Communicating Information on the Condition of Terrestrial Ecosystems, A Focused Investigation of Indicators of Terrestrial Ecosystem Health (initial draft)</i> .   |               |    |    | X  |    |    |   |   |
| 46       | USEPA              | Fabrizio, M.C., C.P. Ferreri and M.J. Hansen. 1995. <i>Prey Fish Communities as Indicators of Ecosystem Health in Lake Michigan</i> . 130 pp.   | X             |    |    |    |    |    |   |   |
| 47       | USEPA              | USEPA. 1990. <i>Environmental Monitoring and Assessment Program (EMAP) Ecological Indicators</i> . ~425 pp.   |               | X  | X  |    |    |    |   |   |
| 48       | USEPA              | Keough, J.R. and J. Griffin. 1994. <i>Technical Workshop on Environmental Monitoring and Assessment Program (EMAP) Indicators for Great Lakes Coastal Wetlands, Summary Report</i> .                                      |               |    | X  |    |    |    |   |   |
| 50       | OMNR/NYSDEC        | OMNR/NYSDEC. 1994. <i>Ecosystem Watch: Status of the Lake Ontario Ecosystem</i> . 8 pp.   | X             |    |    |    |    |    |   |   |
| 51       | CCFM               | Canadian Council of Forest Ministers. 1997. <i>Criteria and Indicators of Sustainable Forest Management in Canada, Technical Report</i> . 137 pp.   |               |    |    | X  |    |    | X |   |
| 52       | State of Minnesota | State of Minnesota. 1997. <i>Environmental Indicators Initiative (Draft)</i> .  |               |    |    | X  |    |    |   |   |
| 53       | GLC                | Great Lakes Commission. 1996. <i>An Agricultural Profile of the Great Lakes Basin: Characteristics and Trends in Production, Land-use and Environmental Impacts</i> .   |               |    |    | X  |    |    |   |   |
| 54       | OECD               | OECD. 1998. <i>OECD Environmental Indicators for Sustainable Development (Draft in Progress)</i> . 117 pp.  |               |    |    | X  |    |    |   |   |
| 55       | NCASI              | LTI-Limno Tech, Inc. 1993. <i>Great Lakes Environmental Assessment</i> . 270 pp.  |               |    |    | X  |    |    |   |   |
| 56       | Health Canada      | Health Canada, Great Lakes Health Effects Program.  |               |    |    |    | X  |    |   |   |
|          | Health Canada      | Riedel, D., N. Tremblay and E. Tompkins (eds). 1997. <i>State of Knowledge Report on Environmental Contaminants and Human Health in the Great Lakes Basin</i> . Great Lakes Health Effects Program. 482 pp.               |               |    |    |    | X  |    |   |   |
|          | Health Canada      | Health Canada. 1998. <i>Persistent Environmental Contaminants and the Great Lakes Basin Population: An Exposure Assessment</i> . Great Lakes Health Effects Program.  |               |    |    |    | X  |    |   |   |
|          | Health Canada      | Health Canada. 1996. "Outdoor Air and Your Health - A Summary of Research Related to Health Effects of Outdoor Air Pollution in the Great Lakes Basin". Great Lakes Health Effects Program.                               |               |    |    |    | X  |    |   |   |
|          | Health Canada      | Health Canada. 1995. "Great Lakes Water and Your Health - A Summary of 'Great Lakes Basin Cancer Risk Assessment: A Case-control Study of Cancers of the Bladder, Colon and Rectum'". Great Lakes Health Effects Program. |               |    |    |    | X  |    |   |   |
|          | Health Canada      | Health Canada. 1992. <i>Atlas I - Birth Defects Atlas of Ontario: 1978-1988</i> . Great Lakes Health Effects Program.   |               |    |    |    | X  |    |   |   |

| Ref. No. | Program Sponsor            | Document Information  | Core Group(s) |    |    |    |    |    |   |
|----------|----------------------------|---|---------------|----|----|----|----|----|---|
|          |                            |   | OW            | NW | CW | NT | HH | LU | S |
|          | Health Canada              | Health Canada. 1992. <i>Atlas II - Cancer Incidence in the Great Lakes Region, Ontario: 1984-1988</i> . Great Lakes Health Effects Program.   |               |    |    |    | X  |    |   |
| 57       | OCTRF                      |   |               |    |    |    | X  |    |   |
| 58       | OMH                        |   |               |    |    |    | X  |    |   |
|          | GLPF/<br>USATSD/<br>NYGLRC | Myers, S. et al. 1996. <i>Report on Incorporating Human Health Considerations into RAPs</i> . 62 pp.  |               |    |    |    | X  |    |   |
|          | NYSDEC                     | Kagey and Stark. 1992. <i>Indicators of Human Reproductive Health within the Great Lakes Drainage Basin Ecosystem</i> . 59 pp.  |               |    |    |    | X  |    |   |
|          |                            | Craan, A.G. and D.A. Haines. 1988 (submitted). "Twenty-five years of surveillance for contaminants in human breast milk". <i>Arch. Environ. Contm. Toxicol.</i>   |               |    |    |    | X  |    |   |
|          |                            | Wang, S.T. et al. "Decline in blood lead in Ontario children correlated to decreasing consumption of leaded gasoline, 1983-1992". <i>Clinical Chemistry</i> . Vol 43, 1251-1252 pp.                         |               |    |    |    | X  |    |   |
| 59       | U of T                     | MacLaren. V.W. 1996. "Urban Sustainability Reporting". <i>Journal of the American Planning Association</i> . Vol. 62, No. 2., 184-201 pp.   |               |    |    |    |    | X  |   |
| 60       | U of T                     | D. Mackay. 1998. Personal Communication. Trent University, Peterborough, Ontario.   | X             |    |    |    |    |    |   |
| 61       |                            | Wackernagel, M. and W. Rees. 1996. <i>Our Ecological Footprint</i> . New Society Publishers, British Columbia, Canada.  |               |    |    |    |    | X  |   |
| 62       | GLC                        | 1994. <i>Ecosystem Charter for the Great Lakes-St. Lawrence Basin</i> .   |               |    |    |    |    |    | X |
| 63       | OMMAH                      | OMMAH. 1998. <i>Performance Indicators for Planning (Pilot Studies). A draft set of planning indicators for pilot study purposes in sample communities in Ontario</i> .                                     |               |    |    |    |    | X  |   |
|          |                            | LURA Group. 1995. <i>Measuring Urban Sustainability: Canadian Indicators Workshop</i> .   |               |    |    |    |    |    |   |
|          | USEPA                      | U.S. Environmental Protection Agency. 1997. <i>Process for Selecting Environmental Indicators and Supporting Data</i> . Data Quality Action Team, EPA Contract No. 68-W4-0031, D04; Washington, D.C., 78pp. |               |    |    |    |    |    |   |

### Core Groups

|    |                          |
|----|--------------------------|
| OW | Open Waters              |
| NW | Nearshore Waters         |
| CW | Coastal Wetlands         |
| NT | Nearshore Terrestrial    |
| HH | Human Health             |
| LU | Socio-economics/Land Use |
| S  | Societal                 |

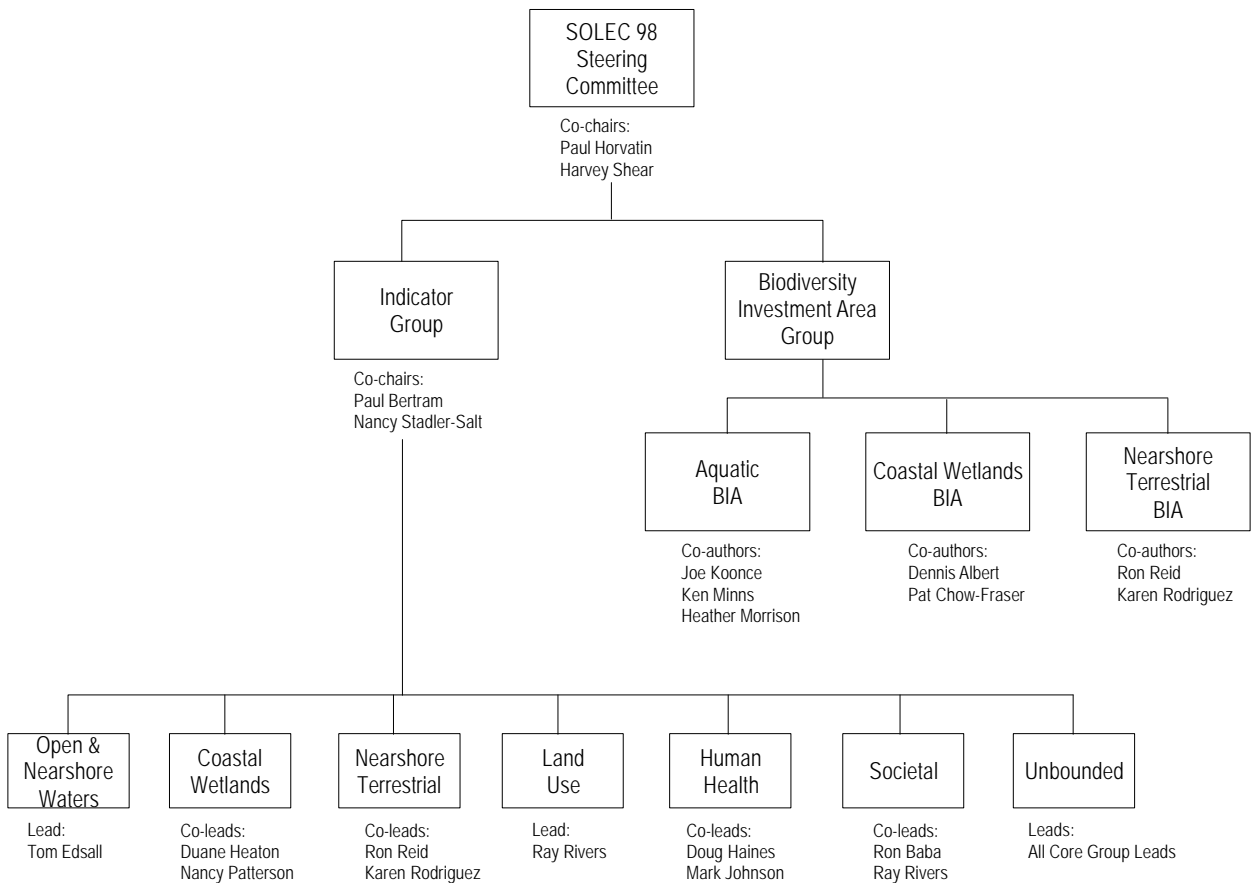
### Glossary of Program Sponsors (alphabetical order)

|      |                                      |
|------|--------------------------------------|
| CCFM | Canadian Council of Forest Ministers |
| EC   | Environment Canada                   |
| GLC  | Great Lakes Commission               |
| GLFC | Great Lakes Fishery Commission       |
| GLPF | Great Lakes Protection Fund          |

|         |   |
|---------|---|
| ICURR   | Intergovernmental Committee on Urban and Rural Research                   |
| IJC     | International Joint Commission  |
| NCASI   | The National Council of the Paper industry for Air and Stream Improvement |
| NYGLRC  | New York Great Lakes Research Consortium                                  |
| NNC     | The Nature Conservancy of Canada  |
| NYSDEC  | New York State Department of Environmental Conservation                   |
| OCTRF   | Ontario Cancer Treatment Research Foundation                              |
| OECD    | Organisation for Economic Co-operation and Development                    |
| OMH     | Ontario Ministry of Health  |
| OMMAH   | Ontario Ministry of Municipal Affairs and Housing                         |
| OMNR    | Ontario Ministry of Natural Resources                                     |
| SOLEC   | State of the Great Lakes Ecosystem Conference                             |
| USATSDR | United States Agency for Toxic Substances and Disease Registry            |
| USEPA   | United States Environmental Protection Agency                             |
| U of T  | University of Toronto   |

# Appendix 8 — Indicator Group, Core Group Members and SOLEC 98 Steering Committee Members

The following chart depicts the SOLEC 98 organizational structure. The members of the Indicator Group, the six Core Groups, and the Steering Committee are listed on the next four pages. This paper does not discuss the Biodiversity Investment Area group—for more information on these papers please visit one of the SOLEC websites:  
<http://www.cciw.ca/solec/>  
<http://www.epa.gov/glnpo/solec/>



## **INDICATOR GROUP** (membership as of October 1998)

### Co-chairs:

Paul Bertram, U.S. Environmental Protection Agency  
Nancy Stadler-Salt, Environment Canada

### Members:

Ron Baba, Oneida Nation  
Tom Edsall, U.S. Geological Survey  
Doug Haines, Health Canada  
Duane Heaton, U.S. Environmental Protection Agency  
Ray Hoff, Environment Canada  
Mark Johnson, U.S. Environmental Protection Agency  
Nancy Patterson, Environment Canada  
Henry Regier, University of Toronto (retired)  
Ron Reid, Bobolink Enterprises  
Ray Rivers, Rivers Consulting  
Karen Rodriguez, U.S. Environmental Protection Agency  
Daniel Smith, Conestoga Rovers, Inc.

### Observers:

Jean Burton, Environment Canada  
John Hartig, International Joint Commission  
John Lawrence, Environment Canada  
Dick Ryder, RAR & Associates

## **OPEN and NEARSHORE WATERS CORE GROUP** (membership as of October 1998)

### Lead:

Tom Edsall, U.S. Geological Survey

### Members:

Scott Brown, Environment Canada  
Randy Eschenroder, Great Lakes Fishery Commission  
Ray Hoff, Environment Canada  
Don Mackay, Trent University  
Mohi Munawar, Dept. of Fisheries & Oceans Canada  
Henry Regier, University of Toronto (retired)  
Wolfgang Scheider, Ontario Ministry of Environment  
William Schertzer, Environment Canada  
Brian Shuter, University of Toronto  
Daniel Smith, Conestoga Rovers, Inc.

### Observers:

Martine Allard, Environment Canada  
Duncan Boyd, Ontario Ministry of Environment  
Uwe Borgman, Environment Canada  
Dan Bauer, U.S. Environmental Protection Agency  
Steve Carpenter, University of Wisconsin  
Murray Charlton, Environment Canada  
John Gannon, U.S. Geological Survey  
Brian F. Lantry, NY State Department of Environmental Conservation  
Mark McMaster, Environment Canada  
Mohi Munawar, Dept. of Fisheries & Oceans Canada  
Scott Painter, Environment Canada  
Trefor Reynoldson, Environment Canada  
Phil Ryan, Ontario Ministry of Natural Resources  
Richard Ryder, retired  
Jim Sherry, Environment Canada  
Gary Sprules, University of Toronto  
William Strachan, Environment Canada

## **COASTAL WETLANDS CORE GROUP** (membership as of October 1998)

### Co-lead:

Duane Heaton, U.S. Environmental Protection Agency  
Nancy Patterson, Environment Canada  
Lesley Dunn, Environment Canada

### Members:

Dennis Albert, Michigan Natural Features Inventory  
Christine Bishop, Environment Canada  
Virginie Bouchard, Ohio State University  
Tom Burton, Michigan State University  
Adele Crowder, Queen's University (retired)  
Jeff Gagler, U.S. Environmental Protection Agency  
Tom Glatzel, U.S. Environmental Protection Agency  
Rich Greenwood, U.S. Fish and Wildlife Service  
Laurie Maynard, Environment Canada  
Kim Santos, U.S. Fish and Wildlife Service  
Bill Schertzer, Environment Canada  
Tom Simon, U.S. Environmental Protection Agency  
Elizabeth Snell, Snell & Cecile Environmental Research  
Ralph Tiner, U.S. Fish and Wildlife Service  
Russ Weeber, Bird Studies Canada

### Observers:

Graham Bryan, Federation of Ontario Naturalists  
Pat Chow-Fraser, McMaster University  
Sue Crispin, The Nature Conservancy  
Bud Harris, University of Wisconsin-Green Bay  
Paul Keddy, University of Ottawa  
Jon McCracken, Bird Studies Canada  
Jim Meeker, Northland College  
T.J. Miller, U.S. Fish and Wildlife Service  
Bill Mitsch, Ohio State University  
Bob Myslik, Environment Canada  
Jim Quinn, McMaster University  
Janice Smith, Environment Canada  
Paul Webb, University of Michigan  
Tom Whillans, Trent University  
Doug Wilcox, U.S. Geological Survey  
Gerald Winn, U.S. Environmental Protection Agency  
Dimos Zarkadas, McMaster University

## **NEARSHORE TERRESTRIAL CORE GROUP** (membership as of October 1998)

### Co-leads:

Ron Reid, Bobolink Enterprises  
Karen Rodriguez, U.S. Environmental Protection Agency

### Members:

John Bacone, Indiana Department of Natural Resources  
David Best, U.S. Fish and Wildlife Service  
William Bowerman, Lake Superior State University  
Sue Crispin, The Nature Conservancy  
Pat Collins, Minnesota Department of Natural Resources  
Thomas Doolittle, Bad River Band of Lake Superior Tribe of  
Chippewa Indians  
Robert Dumke, Wisconsin Department of Natural Resources  
Dave Ewert, The Nature Conservancy  
Michael Gilbertson, International Joint Commission  
Ken Holtje, USDA Forest Service  
Ian Jarvis, Agriculture Canada  
Patrick Lawrence, University of Waterloo  
Tija Luste, Waterfront Regeneration Trust  
Roger Nanne, Natural Resource Conservation Service  
Paul Matthiae, Wisconsin Department of Natural Resources  
Brian McHattie, Environment Canada  
Ralph Moulton, Environment Canada  
Christian Pupp, retired from Environment Canada

### Observers:

Brain Greenwood, University of Toronto  
Fred Johnson, Ontario Ministry of Natural Resources  
Paul Smith, Ontario Heritage Foundation  
Kris West, The Nature Conservancy

## **HUMAN HEALTH CORE GROUP** (membership as of October 1998)

### Co-leads:

Doug Haines, Health Canada  
Mark D. Johnson, U.S. Environmental Protection Agency

### Members:

Diane Dennis-Flagler, U.S. Environmental Protection Agency  
Heraline E. Hicks, Agency for Toxic Substance and Disease  
Registry  
Warren Foster, Health Canada  
Jack Manno, New York Great Lakes Research Consortium

### Observers:

Linda Birnbaum, U.S. Environmental Protection Agency  
Donald Cole, McMaster University  
Larry Fischer, Michigan State University  
Larry Rampie, Chlorine Chemical Council



**LAND USE CORE GROUP** (membership as of October 1998)

Lead:

Ray Rivers, Rivers Consulting

Members:

Roy Aiken, Door Property Owners Assoc., Wisconsin  
John Barr, Municipality of Metropolitan Toronto  
Brad Bass, Environment Canada  
Mike Finney, Oneida Little Bear Devel Centre  
George Francis, University of Waterloo  
Kent Gilges, Center for Compatible Economic Development  
Andrew Hamilton, Commission for Environmental Cooperation  
John Haugland, U.S. Environmental Protection Agency  
Bryan Hill, Ontario Ministry of Municipal Affairs and Housing  
Ian Jarvis, Agriculture and Agri-Food Canada  
James Kay, University of Waterloo  
Virginia MacLaren, University of Toronto  
Tom Muir, Environment Canada  
Walter Mulkewich, Former Mayor of Burlington, Ontario  
Dale Phenicie, Council of Great Lakes Industries  
Bruce Pond, Ontario Ministry of Natural Resources  
Mike Raab, County of Erie, Department of Environment and Planning  
Julie Stoneman, Michigan Environmental Council  
Nancy Strole, Springfield Twp Oakland County, Michigan  
Stephen Thorp, Great Lakes Commission  
Peter Victor, York University  
Margaret Wooster, Great Lakes United

**STEWARDSHIP CORE GROUP** (membership as of October 1998)

Co-leads:

Ron Baba, Oneida Nation  
Ray Rivers, Rivers Consulting

Members:

Robert Brander, Sigurd Olson Environmental Institute, Northland College  
Jean Burton, Environment Canada  
Jim Cantrill, Northern Michigan University  
Margaret Dochoda, Great Lakes Fishery Commission  
Doug Dodge, Ontario Ministry of Natural Resources  
Michael Donahue, Great Lakes Commission  
Michael Finney, Oneida Nation  
George Francis, University of Waterloo  
John Hartig, International Joint Commission  
Anne Kerr, Environment Canada  
Joanna Kidd, LURA Consulting  
Sally Lerner, University of Waterloo  
Jack Manno, New York Great Lakes Research Consortium  
Dale Phenicie, Council of Great Lakes Industries  
Ray Rivers, Rivers Consulting  
Margaret Shannon, SUNY Buffalo Law School  
Madelyn Webb, Association for Canadian Educational Resources  
Leslie Woo, Waterfront Regeneration Trust  
Margaret Wooster, Great Lakes United

## **SOLEC 98 STEERING COMMITTEE MEMBERS** (membership as of October 1998)

### Co-chairs:

Paul Horvatin, U.S. Environmental Protection Agency, GLNPO  
Harvey Shear, Environment Canada, RDG-OR

### Members:

Dan Bauer, USGS Water Resources Division  
Judy Beck, U.S. Environmental Protection Agency, Region 5  
Paul Bertram, U.S. Environmental Protection Agency, GLNPO  
Kelly Burch, Pennsylvania Department of Environmental Protection  
Jean Burton, Environment Canada, Centre St. Laurent  
Dieter Busch, U.S. Fish and Wildlife Service, Lower Great Lakes Fishery Resources Office  
William Cibelus, Association for Toxic Substances and Disease Registry  
Marg Dochoda, Great Lakes Fishery Commission  
Doug Dodge, Ontario Ministry of Natural Resources  
Michael Donahue, Great Lakes Commission  
Richard Draper, New York State Department of Environmental Conservation  
Tim Eder, National Wildlife Federation  
Fred Fleischer, Ontario Ministry of Environment  
Kent Fuller, U.S. Environmental Protection Agency, GLNPO  
John Gannon, Chief, U.S. Geological Survey  
Sandra George, Environment Canada, ECB  
Rich Greenwood, U.S. Environmental Protection Agency, GLNPO  
Margaret Guerriero, U.S. Environmental Protection Agency, Region 5  
John Hartig, International Joint Commission  
Duane Heaton, U.S. Environmental Protection Agency, GLNPO  
Dan Helwig, Minnesota Pollution Control Agency  
Ray Hoff, Environment Canada, Centre for Atmospheric Research Experiments  
Brett Hulsey, Sierra Club  
Anne Kerr, Environment Canada, Ecosystem Science Directorate  
Gail Krantzberg, Ontario Ministry of Environment  
Bob Kraska, U.S. Fish and Wildlife Service  
Jacinthe Leclerc, Environment Canada, S.L. Vision 2000  
G. Tracy Mehan, Michigan Department of Environmental Quality  
Gerry Mikol, New York State Department of Environmental Conservation  
Susan Nameth, Environment Canada, Great Lakes Environmental Office  
Francine Norling, U.S. Environmental Protection Agency, Reg. 5  
Dale Phenicie, Council of Great Lakes Industries  
Dieter Riedel, Health Canada, Environmental Health Directorate  
Ray Rivers, Rivers Consulting  
Peter Roberts, Ontario Ministry of Agriculture, Food and Rural Affairs  
Barbara Spinweber, U.S. Environmental Protection Agency, Region 2  
Nancy Stadler-Salt, Environment Canada, RDG-OR  
Helen Taylor, The Nature Conservancy  
Edward Tompkins, Environment Canada, GLCA  
Karen Thompson, U.S. Environmental Protection Agency, Region 5, Office of Public Affairs  
Steve Thorp, Great Lakes Commission  
Jack Weinberg, Greenpeace  
Margaret Wooster, Great Lakes United  
Maggie Young, Environment Canada, RDG-OR

### Observers:

James Addis, Wisconsin Department of Natural Resources  
Janette Anderson, Environment Canada, ECB  
Kathy Baird, Indiana Department of Environmental Management  
John Barr, Director of Metro Planning, Toronto  
Steve Brandt, NOAA/GLERL  
Lee Bridges, Indiana Department of Environmental Management  
Murray Brooksbank, Environment Canada, Great Lakes Environment Office  
Allegra Cangelosi, Northeast-Midwest Institute  
Patrick T. Collins, Minnesota Department of Natural Resources  
Kirby Cottrell, Director, Illinois Department of Natural Resources  
Nicholas Damato, U.S. Environmental Protection Agency, Reg. 5  
Joseph DePinto, University of Buffalo  
Dale Engquist, U.S. National Park Service, Indiana Dunes National Lakeshore  
Dr. Chris Goddard, Great Lakes Fishery Commission  
Steve Hedtke, U.S. EPA, Environmental Effects Research Laboratory  
Roland Hemmett, U.S. Environmental Protection Agency, Reg. 2  
Heraline E. Hicks, Agency for Toxic Substances and Disease Registry  
Ken Holtje, Director, USDA - Forest Service  
Ava Hottman, Ohio Environmental Protection Agency  
Peter Jones, New York State Department of Environmental Conservation  
Virginia Kibler, U.S. Environmental Protection Agency, Headquarters (Alternate - Mark Morris)  
Chuck Ledin, Wisconsin Department of Natural Resources  
Steve Lozano, U.S. EPA, Environmental Effects Research Laboratory  
Percy Magee, Natural Resources Conservation Service  
Jan Miller, U.S. Army Corps of Engineers  
Barbara McLeod, U.S. Environmental Protection Agency, Headquarters  
Roger Nanney, U.S. Environmental Protection Agency, GLNPO  
Carl Nash, U.S. Environmental Protection Agency, Region 5  
Darrell Piekarz, Environment Canada, ECB  
Phil Pope, Purdue University, Sea Grant Program  
James Ray, Indiana Department of Natural Resources  
M. Eric Reeves, Commander, US Coast Guard  
Charles Sapp, U.S. Environmental Protection Agency, Region 3  
Bob Schacht, Illinois Environmental Protection Agency  
Jake Vanderwal, Lake Superior Programs Office  
Jerry Wager, Ohio Department of Natural Resources  
Peter L. Wise, Illinois Environmental Protection Agency  
Patty Yount, Indiana Department of Environmental Management  
James Zorn, Great Lakes Indian Fish & Wildlife Commission

# Appendix 9 — Revisions Since Version 2 of the SOLEC 98 Indicator List

## Indicator # Indicator Name

### Nearshore and Open Waters

#### State Indicators

|     |  |
|-----|--|
| 6   | Aquatic Habitat  |
| 8   | Salmon and Trout   |
| 9   | Walleye and <i>Hexagenia</i>                               |
| 17  | Preyfish Populations                                       |
| 68  | Native Unionid Mussels                                     |
| 93  | Lake Trout and Scud ( <i>Diaporeia hoyi</i> )              |
| 101 | Deformities, Erosion, Lesions and Tumors in Nearshore Fish |
| 104 | Benthos Diversity and Abundance                            |
| 109 | Phytoplankton Populations                                  |
| 116 | Zooplankton Populations as Indicators of Ecosystem Health  |

#### Pressure Indicators

|                |   |
|----------------|---|
| 18             | Sea Lamprey   |
| 72             | Fish Entrainment  |
| 111            | Phosphorus Concentrations and Loadings  |
| <del>112</del> | <del>Trends in Contaminant Concentrations &amp; Loadings in: Water, Air, Soil and Sediments - split into 4 new indicators: 117, 118, 119, &amp; 120</del> |
| 113            | Contaminants in Recreational Fish   |
| 114            | Contaminants in Young-of-the-Year Spottail Shiners  |
| 115            | Contaminants in Colonial Nesting Waterbirds   |
| <b>117</b>     | <b><i>Atmospheric Deposition of Toxic Chemicals</i> - new indicator, split out of 112</b>   |
| <b>118</b>     | <b><i>Toxic Chemical Concentrations in Offshore Waters</i> - new indicator, split out of 112</b>  |
| <b>119</b>     | <b><i>Concentrations of Contaminants in Sediment Cores</i> - new indicator, split out of 112</b>  |
| <b>120</b>     | <b><i>Contaminant Exchanges Between Media: Air to Water and Water to Sediment</i> - new indicator, split out of 112</b>                                   |

### Coastal Wetlands

#### State Indicators

|                 |  |
|-----------------|--|
| 4501            | Coastal Wetland Invertebrate Community Health                          |
| 4502            | Coastal Wetland Fish Community Health                                  |
| 4503            | Deformities/Eroded Fins/Lesions/Tumours (DELT) in Coastal Wetland Fish |
| 4504            | Amphibian Diversity and Abundance                                      |
| <del>4505</del> | <del>Reptile Diversity and Abundance - deleted</del>                   |
| 4507            | Wetland-Dependent Bird Diversity & Abundance                           |
| 4510            | Coastal Wetland Area by Type   |
| 4511            | Gain in Restored Coastal Wetland Area by Type                          |
| <del>4512</del> | <del>Chlorophyll a Levels - deleted</del>                              |
| 4513            | Presence, Abundance & Expansion of Invasive Plants                     |
| <del>4859</del> | <del>Reproductive Output of Mink - deleted</del>                       |
| 7055            | Habitat Adjacent to Coastal Wetlands - moved from Land Use Group       |

#### Pressure Indicators

|                 |   |
|-----------------|---|
| 4506            | Contaminants in Snapping Turtle Eggs  |
| 4516            | Sediment Flowing into Coastal Wetlands  |
| <del>4518</del> | <del>Water Level Fluctuations - combined with 8133 into new indicator 4861</del>                      |
| <del>4854</del> | <del>Water Quality: Chlorides Flowing into Coastal Wetlands - deleted</del>                           |
| <del>4855</del> | <del>Water Quality: Nitrates into Coastal Wetlands - combined with 4856 into new indicator 4860</del> |

- ~~4856~~ ~~Water Quality: Total Phosphorus Flowing into Coastal Wetlands - combined with 4855 into new indicator 4860~~
- 4860** **Nitrates and Total Phosphorus Into Coastal Wetlands** - new indicator, combines 4855 & 4856
- 4861** **Water Level Fluctuations** - new indicator, combines 4518 & 8133

## Nearshore Terrestrial

### State Indicators

- ~~8128~~ ~~Nearshore Threatened Species - combined with 8148, 8151 & 8152 into new indicator 8161~~
- 8129 Area, Quality, and Protection of Special Lakeshore Communities
- 8136 Extent and Quality of Nearshore Natural Land Cover
- 8137 Nearshore Species Diversity and Stability
- ~~8148~~ ~~Nearshore Endemic Species - combined with 8128, 8151 & 8152 into new indicator 8161~~

### Pressure Indicators

- 8131 Extent of Hardened Shoreline
- 8132 Nearshore Land Use Intensity
- ~~8133~~ ~~Lake Level Fluctuations - combined with 4518 into new indicator 4861~~
- 8134 Nearshore Plant and Wildlife Problem Species
- 8135 Contaminants Affecting Productivity of Bald Eagles
- 8146 Artificial Coastal Structures
- 8147 Contaminants Affecting the American Otter
- 4861** **Water Level Fluctuations** - new indicator, combines 4518 & 8133

### Human Activity (Response) Indicators

- 8139 Community / Species Plans
- ~~8140~~ ~~Financial Resources Allocated to Great Lakes Programs - moved into Societal Group~~
- 8141 Shoreline Managed Under Integrated Management Plans
- 8149 Nearshore Protected Areas

### Basin-wide Indicators

- ~~8150~~ ~~Breeding Bird Diversity and Abundance - moved into Land Use Group~~
- ~~8151~~ ~~Number, Extent, and Viability of Endemic Species - combined with 8128, 8148 & 8152 into new indicator 8161~~
- ~~8152~~ ~~Threatened Species - combined with 8128, 8148 & 8151 into new indicator 8161~~

## Human Health

### State Indicators

- 4179 Geographic Patterns and Trends in Disease Incidence

### Pressure Indicators

- 4081 Fecal Pollution Levels of Nearshore Recreational Waters
- 4083 Chemical Contaminants in Fish Tissue
- 4088 Chemical Contaminant Intake From Air, Water, Soil and Food
- 4175 Drinking Water Quality
- 4176 Air Quality
- 4177 Chemical Contaminants in Human Tissue
- 4178 Radionuclides

## Land Use

### State Indicators

- ~~7027~~ ~~Loss of Natural Features - deleted~~
- ~~7042~~ ~~Aesthetics - moved into Societal Group~~
- ~~7043~~ ~~Economic Prosperity - moved into Societal Group~~
- ~~7055~~ ~~Habitat Adjacent to Coastal Wetlands - moved into Coastal Wetlands Group~~
- 8150 Breeding Bird Diversity and Abundance - moved from Unbounded Group
- 8161** **Threatened Species** - new indicator, combines 8128, 8148, 8151 & 8152

### Pressure Indicators

- 7000 Urban Density

7002 Land Conversion  
~~7007 Resource Use - split into 7056 & 7057~~  
 7012 Mass Transportation  
~~7017 Pollution Levels - split into 7058, 7059 & 7060~~  
~~7054 Ground Surface Hardening - deleted~~  
**7056 Water Consumption - new indicator, split out of 7007**  
**7057 Energy Consumption - new indicator, split out of 7007**  
~~7058 Ground Level Ozone - new indicator, split out of 7017, then combined with 4176~~  
**7059 Wastewater Pollutant Loading - new indicator, split out of 7017**  
**7060 Solid Waste Generation - new indicator, split out of 7017**  
~~8111 Agricultural Intensity - deleted~~  
 8114 Habitat Fragmentation  
 8142 Stream Flow  
*Human Activity (Response) Indicators*  
 7006 Brownfield Redevelopment  
 7028 Sustainable Agricultural Practices  
 7053 Green Planning Process

## Societal Indicators

### State Indicators

7042 Aesthetics - moved from Land Use Group  
 7043 Economic Prosperity - moved from Land Use Group

### Human Activity (Response) Indicators

3509 Capacities of Sustainable Landscape Partnerships - unchanged from SOLEC 98  
 3510 Organizational Richness of Sustainable Landscape Partnerships - unchanged from SOLEC 98  
 3511 Integration of Ecosystem Management Principles Across Landscapes - unchanged from SOLEC 98  
 3512 Integration of Sustainability Principles Across Landscapes - unchanged from SOLEC 98  
 3513 Citizen / Community Place-Based Stewardship Activities - unchanged from SOLEC 98  
 8140 Financial Resources Allocated to Great Lakes Programs - moved from Nearshore Terrestrial Group

## Unbounded

### State Indicators

9001 Atmospheric Visibility: Prevention of Significant Deterioration  
~~8150 Breeding Bird Diversity and Abundance - moved into Land Use Group~~  
~~8151 Number, Extent, and Viability of Endemic Species - combined with 8128, 8148 & 8152 into new indicator 8161~~  
~~8152 Threatened Species - combined with 8128, 8148 & 8151 into new indicator 8161~~

### Pressure Indicators

~~112 Trends in Contaminant Concentrations & Loadings in: Water, Air, Soil and Sediments - split into 4 new indicators: 117, 118, 119, & 120~~  
 4519 Global Warming: Number of Extreme Storms  
 4857 Global Warming: First Emergence of Water Lilies in Coastal Wetlands  
 4858 Global Warming: Ice Duration on the Great Lakes  
 9000 Acid Rain

Total number of indicators = 80

(Please note: Indicator #4861 Water Level Fluctuations is listed twice since it is an integrated indicator belonging to both the Coastal Wetlands and Nearshore Terrestrial groups)