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Development and application of ecosystem health indicators in the North American Great Lakes Basin

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Abstract

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

1 Introduction

The purpose of the Great Lakes Water Quality Agreement (GLWQA) between the United States and Canada is "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem" [1]. The Agreement also calls for the development of ecosystem health indicators. Environmental and natural resource management agencies are now trying to demonstrate that past remediation programs have been successful, and that the results of future or continuing programs will be positive and proportionate to the resources expended (financial and personnel time).

Assessing the health of the Great Lakes Basin ecosystem is a significant challenge. The Lakes themselves contain one-fifth of the world's fresh surface water with over 17,000 kilometres of shoreline. The basin consists of over 520,000 square kilometres of land with about 33.5 million people living there. The basin is governed by two nations, eight states, one province, and hundreds of municipal and local governments. A set of Great Lakes basin ecosystem indicators will enable the Great Lakes community to work together within a consistent framework to assess and monitor changes in the state of the ecosystem, and will facilitate more efficient monitoring and reporting programs.

Ecosystem health can be measured to some degree and characterized as having 7 key properties [2]. They are:

(1) free from ecosystem distress syndrome; (2) resilient; (3) self-sustaining; (4) do not impair adjacent ecosystems; (5) free from risk factors; (6) economically viable; and (7) capable of sustaining healthy human populations.

Callicott [3] concluded that ecosystems do exist as sets of process functions within temporal boundaries, and that ecosystem health is an objective condition that can be measured, albeit with an overlay of societal values. Society is beginning to recognize that to achieve that health, socio-economic trade offs will be necessary, and the natural history of the resource must be recognized [4].

In Great Lakes, the ecosystem is given a spatial boundary, namely the watershed of the Great Lakes Basin. The temporal component to the definition is any arbitrary time chosen for management action or investigation. More importantly, the ecosystem approach is the defining mechanism by which management agencies are to carry out their research and deliver their regulatory programs [1, 5, 6, 7, 8]. In real terms, the ecosystem approach has come to mean a comprehensive approach to environmental issues, considering the interacting living (including humans) and non-living components of the Great Lakes basin.

With respect to the health of the Great Lakes, scientists and non-scientists have now engaged in the development of appropriate ecosystem indicators [9, 10, 11, 12]. At present, there is a continuum of proposed indicators from ones which are most easily understood by the non-scientific public to those understood by the scientific community. The indicators developed and explained in this paper fall into the former category.

An indicator is a parameter or value that reflects the condition of an environmental (or human health) component, usually with a significance that extends beyond the measurement or value itself [13]. Used alone or in combination, indicators provide the means to assess progress toward one or more objectives: are conditions improving so that the objective is closer to being met, or are conditions deteriorating? The achievement of these objectives leads towards achievement of higher order goals and vision for the ecosystem.

The purpose of this paper is to present information on some of the indicators representing various ecosystem components. Over time, as the data sets become more complete as a time series, we will be able to draw conclusions regarding the trends in ecosystem components illustrated by the indicators, and relate them to ecosystem goals and objectives.

2 Indicator selection

The State of the Lakes Ecosystem Conferences (SOLEC) were established by the governments of Canada and the United States in 1992 in response to reporting requirements of the GLWQA [1].

To guide the development of a suite of indicators for the Great Lakes basin ecosystem, the SOLEC organizers built upon the work of others both in the Great lakes and worldwide; focused on broad spatial scales reflecting the whole Great Lakes basin, whole lake watersheds, and sub-basins of the larger Lakes; selected a framework for subdividing the Great Lakes Basin ecosystem based on geographic zones and non-geographic issues; and selected an indicator system. There are several classification schemes or models for indicators [14, 15, 16, 17, 18] one of which is the State-Pressure-Human Activity (Response) model [19, 20]. The S-P-A model is simple and broadly applicable and was selected as the system for Great Lakes indicators. The selection process for the Great Lakes indicator suite is described in detail in Bertram et al. [12].

At SOLEC 2002, reports were presented on 45 of the 84 indicators. These 45 were selected because data were readily available. The indicators were discussed in workshop sessions, and comments, criticisms, and suggestions for improvements were noted. After SOLEC 2002, the indicator reports were posted on the SOLEC websites for several months to solicit additional input. Refinements will be made to some of the indicators before the State of the Great Lakes, 2003 report is released in mid 2003.

Data for a few of the 45 indicators are not yet basin-wide. In other cases only some of the data for the indicators were presented. The remaining indicators have yet to be reported because the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs may be necessary. Additionally, some indicators are still in the development stage. Over time, as monitoring and reporting on the full suite of indicators is implemented, we will have a clearer, more complete picture of the health of the Great Lakes basin ecosystem.

3 Some results from selected indicators

3.1 Ecosystem health

3.1.1 *Hexagenia*

The distribution, abundance, biomass, and annual production of the burrowing mayfly *Hexagenia* in mesotrophic Great Lakes habitats are measured directly. These metrics are used as the indicator of ecosystem health because *Hexagenia* is intolerant of pollution, and is therefore a good reflection of water and lake bed sediment quality in mesotrophic Great Lakes habitats. *Hexagenia* was historically the dominant, large, benthic invertebrate in these habitats, and was an important item in the diets of may valuable fishes. Figure 1 shows the populations of *Hexagenia* in Western Lake Erie over the past 11 years, with a clear indication of a population recovery [21].

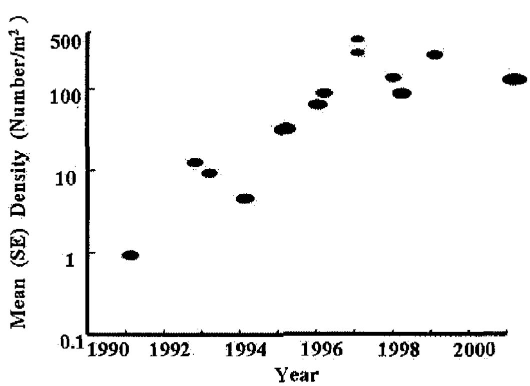

Figure 1: Density of *Hexagenia* in Western Lake Erie.

3.1.2 Sea Lamprey populations

This indicator estimates the abundance of sea lampreys as an indicator of the status of this invasive species, and of the damage it causes to the fish communities and aquatic ecosystems of the Great Lakes. Populations of native top predator, lake trout, and other fishes are negatively affected by mortality caused by sea lampreys. Figure 2 presents these lake-wide estimates since 1980 [22].

3.1.3 Contaminants affecting the productivity of bald eagles

This indicator assesses the number of territorial pairs, success rate of nesting attempts, and number of fledged young per territorial pair as well as the number of developmental deformities in young. The concentrations of persistent organic pollutants and selected heavy metals are also determined in unhatched bald eagle eggs, and in nestling blood and feathers.

Figure 3 shows the effects on eagle populations in the Great Lakes. The number of occupied territories has steadily risen for four of the Great Lakes, and in 2000, a pair of eagles was observed nesting on Lake Ontario [23].

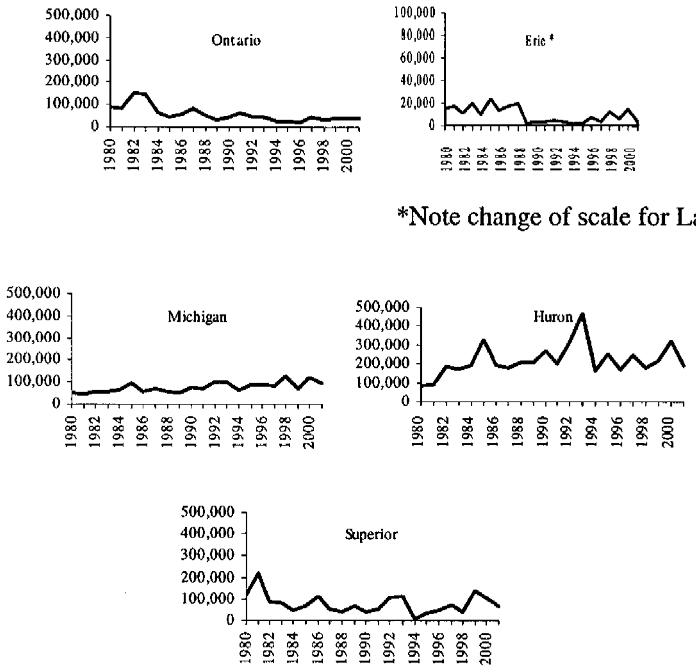

Figure 2: Lakewide estimates of adult sea lamprey populations.

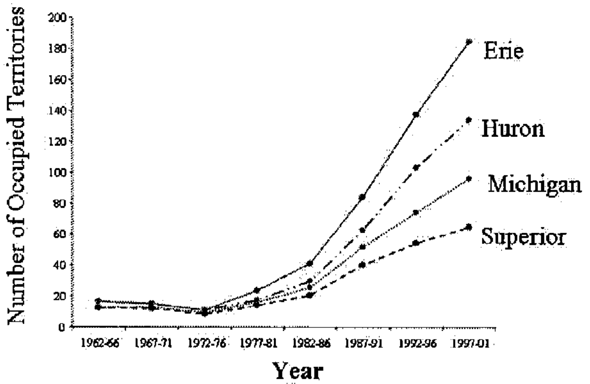

Figure 3: Average number of occupied bald eagle territories per year by lake.

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3.1.4 Phosphorus concentrations and loadings

This indicator assesses total phosphorus levels in the Great Lakes, and is used to support the evaluation of trophic status and food web dynamics in the Great Lakes. Efforts begun in the 1970s to reduce phosphorus loadings have been successful in maintaining or reducing nutrient concentrations in the Lakes, although high concentrations still occur locally in some embayments and harbours. Phosphorus loads have decreased in part due to changes in agricultural practices (e.g., conservation tillage and integrated crop management), promotion of phosphorus-free detergents, and improvements made to sewage treatment plants and sewer systems.

Figure 4 shows the average concentrations in the open waters of Lakes Superior, Michigan, Huron, and Ontario are at or below expected levels [24]. Concentrations in the three basins of Lake Erie fluctuate from year to year, and frequently exceed target concentrations. In Lakes Ontario and Huron, although most offshore waters meet the desired guideline, some offshore and nearshore areas and embayments experience elevated levels which could promote nuisance algae growths such as the attached green algae, *Cladophora.*

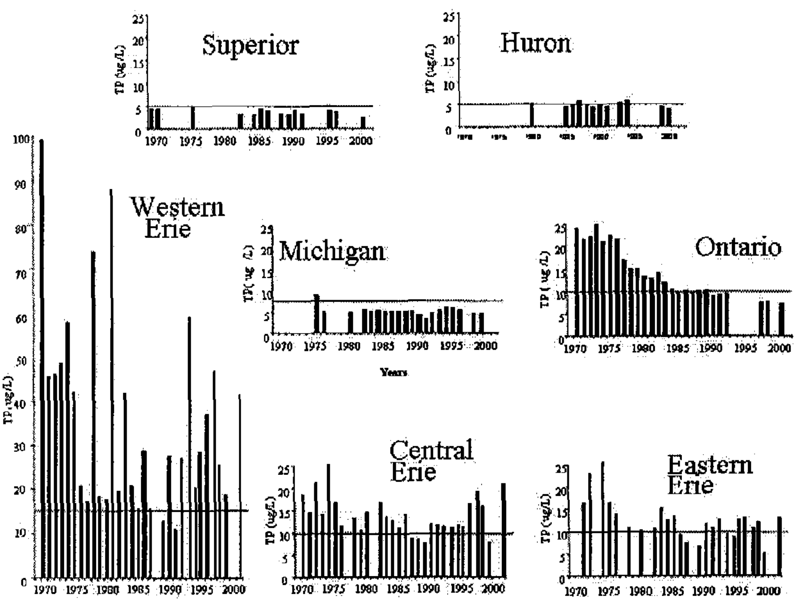

Figure 4: Phosphorus concentrations in the Great Lakes 1970-2002.

3.1.5 Contaminants in colonial nesting waterbirds

This indicator assesses current chemical concentration levels and trends as well as ecological and physiological endpoints in representative colonial waterbirds (gulls, terns, cormorants and/or herons). These features will be used to infer and

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measure the impact of contaminants on the health. An example of the kind of information provided by this indicator is shown figure 5 [25]. Levels of DDE in herring gull eggs are shown for a time series from 1974-2001.

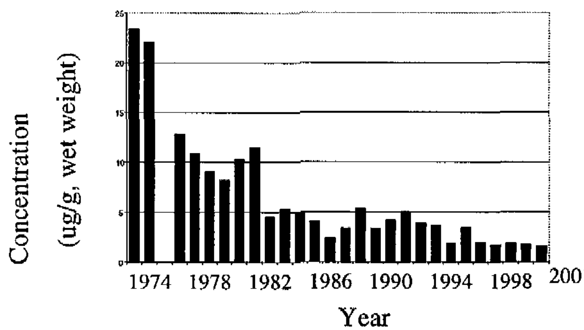

Figure 5: Concentrations of DDE in herring gull eggs, Lake Ontario. 1974-2001.

3.1.6 Wetland dependent bird diversity and abundance

Assessments of wetland-dependent bird diversity and abundance in the Great Lakes basin are used to evaluate health and function of coastal and inland wetlands. Breeding birds are valuable components of Great Lakes wetlands and rely on physical, chemical and biological health of their habitats. Because these relationships are particularly strong during the breeding season, presence and abundance of breeding individuals can provide a source of information about wetland status and trends. When long-term monitoring data are combined with an analysis of habitat characteristics, trends in species abundance and diversity can contribute to an assessment of how well Great Lakes coastal wetlands are able to support birds and other wetland-dependent wildlife. Populations of several wetland-dependent birds are believed to be at risk due to continuing loss and degradation of their habitats. Figure 6 [26] shows results for 4 bird species.

While 5 years of data are not enough to draw any definitive conclusions, clearly the trends in these populations are declining or at best remaining static.

3.2 Human health

3.2.1 Contaminants in edible fish tissue

This indicator assesses the historical trends of the edibility of fish in the Great Lakes using fish contaminant data and a standardized fish advisory protocol. The approach is illustrated in figure 7 where two of the Great Lakes are shown [27]. The various action levels for human consumption of fish are shown as horizontal lines with the corresponding action level noted. Unfortunately data gaps and data variability do not allow one to discern statistically significant trends at this time. Nevertheless, since the 1970's, there have been declines in many persistent bioaccumulative toxic (PBT) chemicals in the Great Lakes basin. However, these chemicals, continue to be a significant concern regarding fish consumption.

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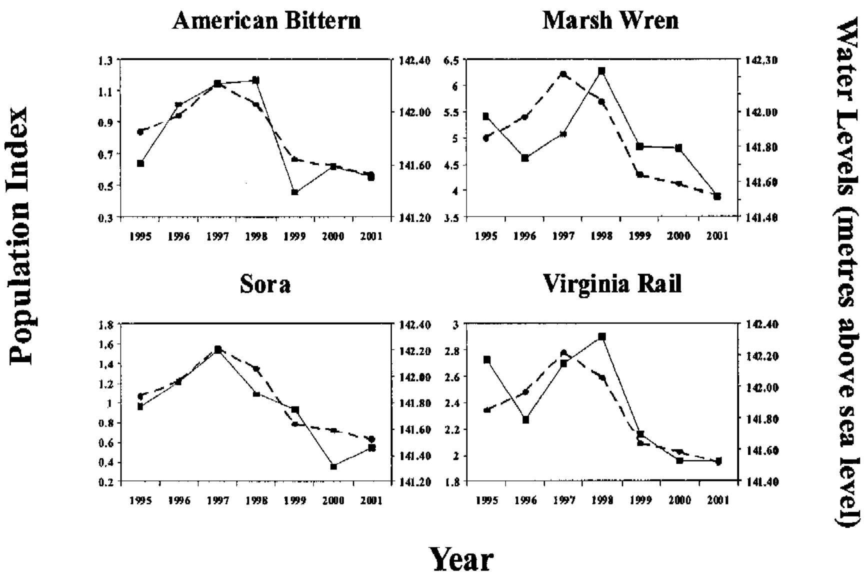

Figure 6: Population indices for selected wetland dependent birds.

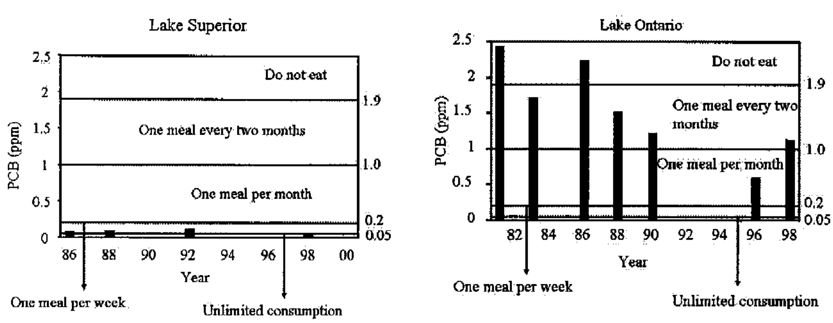

Figure 7: PCB Concentration in edible fish tissue in each Great Lake.

4 Summary

This paper has presented information on a limited number of examples of Great Lakes indicators. More information can be found in the State of the Great Lakes, 2001 [28]. The entire suite of indicators addresses most of the Great Lakes ecosystem components. The indicator list is dynamic and indicators may be added or dropped as required by Great Lakes managers.

Several challenges remain to fully implement the indicators. They include the following:

- Gaining acceptance of the list by various levels of government;
- Building appropriate monitoring and reporting activities into Great Lakes programs; and
- Reporting on indicators in a format that will meet the needs of multiple users.

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