SOLEC 2002

# PROPOSED CHANGES TO THE GREAT LAKES INDICATOR SUITE

**DRAFT FOR DISCUSSION AT SOLEC 2002**

**OCTOBER 2002**

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## Proposed Changes to the Great Lakes Indicators Suite

October, 2002

This document presents information to SOLEC participants about the development of Great Lakes indicators since the release of Selection of Indicators for Great Lakes Basin Ecosystem Health - Version 4. Included are proposed changes to the organizing framework (or Core Group structure) as well as proposed changes to the indicators - whether that be additions of new indicators, revisions of current indicators or the deletion of an indicator.

Indicators have been considered, and are being proposed for the ecosystem components of forests, groundwater, agriculture, societal responsibility, and biological integrity. Several other changes to the SOLEC indicator list are also proposed and are included in this paper.

# SOLEC 2002

## Proposed Changes to the Great Lakes Indicators Suite

October, 2002

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# 1. Revised Great Lakes Indicator Framework

(Changes to the SOLEC Core Group Structure)

Currently the Core Group structure (or organizing framework) is as follows:

| | |
|---|---|
| 3 geographic zones: | Open and Nearshore Waters |
| | Coastal Wetlands |
| | Nearshore Terrestrial |
| 3 "issues": | Land Use |
| | Human Health |
| | Societal |
| 1 cross-cutting: | Unbounded |

When potential new indicators are proposed to fill gaps in the Great Lakes indicator suite (ie. forestry, groundwater, tributaries, inland lakes & wetlands, mining...) it is quickly recognized that this structure will not work.

The SOLEC Organizing Committee propose the following change to structure:

| | |
|---|---|
| 4 geographic zones: | Open and Nearshore Waters |
| | Coastal Wetlands |
| | Nearshore Terrestrial |
| | The Great Lakes Watershed |
| 2 "issues": | Human Health |
| | Societal |
| | - Urban Issues |
| | - Socio-economics |
| | - Societal Response |
| 1 cross-cutting: | Unbounded |

C The "Watershed" group would expand the terrestrial component inland from the nearshore area. It would incorporate the new geographic components (forestry, tributaries, groundwater, mining, inland waters and wetlands, as well as better agriculture indicators) plus some indicators from the old Land Use group (land conversion, sustainable agricultural practices, habitat adjacent to coastal wetlands, & habitat fragmentation).

C Under Societal, a sub-group called Urban Issues has been created and the other Land Use indicators will be moved here (urban density, brownfield redevelopment, mass transportation, green planning process, *plus* aesthetics, water withdrawal, energy consumption, & solid waste generation).

C The two other newly created sub-groups in Societal are Socio-Economics (which would include the indicators economic prosperity, financial resources allocated to Great Lakes programs, plus indicators on the "effect of the environment on society") and Societal Response (ie. citizen/community place-based stewardship activities, plus other indicators proposed later in this report).

The SOLEC Organizing Committee recognizes that incorporating indicators for each of these new "components" will lead to increasing numbers of indicators in the Great Lakes indicator suite. They have suggested that the experts also develop indices and linkages with the current indicators at the same time as proposing new indicators. Further work on linkages and indices will take place in the near future.

## 2. Process for Changes to the Great Lakes Indicator Suite

(To add, delete and/or revise indicators)

The following are the steps to make changes to the current indicator suite:

- The indicator process will be opened for additions, deletions and revisions once per year - it is suggested that this take place in the spring (March to May). This will be announced to the Core Group leaders and Steering Committee members.

- The Core Group leader or Steering Committee member proposes new indicator(s), change(s) or deletion(s) and submits them to the SOLEC Indicator Coordinators.

- The Indicator Coordinators edit, then distribute the proposed changes to the Steering Committee members, other Core Group leaders and/or expert panels for review.

- Steering Committee members, other Core Group leaders and/or expert panels provide comments on the proposed changes directly or seek advice of other experts.

- Comments/revisions are incorporated by the Core Group leaders or Indicator Coordinators, these plus the proposed indicator(s) and suggested deletion(s) are prepared for distribution prior to upcoming SOLEC (ie. this paper - *Proposed Changes to the Great Lakes Indicator Suite*). The review would include posting to the internet, announcements to a broader Great Lakes audience, and leaving the revised/new indicators open for comments for 2 months following SOLEC.

- Feedback will be requested on the revised/new indicator(s) with emphasis on whether it meets the general SOLEC criteria of necessary, sufficient and feasible. Other specific and general comments will be considered.

- Feedback will be sent to the appropriate Core Group leader or expert panels to deal with - that group may need to write a justification as to why they are keeping indicator in the suite if reaction was generally mixed. This would take place in January and February of a non-SOLEC year.

- The Indicator Coordinators will write a resolution to potential changes for that year and post to the SOLEC web site. This would take place in the spring of a non-SOLEC year.

# 3. Indicators of Biological Integrity

A separate paper has been prepared discussing the use of some of the Great Lakes indicators in order to determine the state of Biological Integrity in the Great Lakes. In order to begin this task a workshop was held in December of 2001 to look at the current suite of Great Lakes indicators from this perspective. Note that the list was never designed to measure Biological Integrity. The workshop focussed on a major stress to Biological Integrity: non-native species. The work was continued further in the summer of 2002 by working with the Lakewide Management Plan Committees to identify and survey a series of experts in order to broaden the scope of stresses on Biological Integrity and how the current suite of Great Lakes indicators can be used to determine the state of Biological Integrity.

Some of the current indicators have had revisions proposed, and there are three proposed new indicators. Please see the draft document called "Evaluating Biological Integrity in the Great Lakes" for more detail on the process and for a discussion on the proposed revised indicators and proposed new indicators.

The following is a list of indicators that have been revised and their descriptions are included in the "Evaluating Biological Integrity in the Great Lakes" draft paper:

Fish Habitat (indicator #6)
Naturalized Salmon and Trout (indicator #8)
Walleye (indicator #9)
*Hexagenia* (indicator #9a)
Preyfish Populations (indicator #17)
Lake trout (indicator #93)
*Diporeia* (indicator #93a)
Benthic Biomass: Production Yield, Diversity and Abundance (indicator #104)
Zooplankton Populations (indicator #116)
Land Use (indicator #8132)

The following is a list of proposed new indicators that are described in the "Evaluating Biological Integrity in the Great Lakes" draft paper:

Health of Terrestrial Plant Communities
Landscape Ecosystem Health
Status and Protection of Special Places and Species

# 4. Societal Response Indicators

## 4a. Societal response indicator project

The Great Lakes suite of indicators are designed to assess the progress toward a healthier and more sustainable Great Lakes ecosystem. A healthy and sustainable ecosystem is one that achieves a balance between environmental integrity, economic viability and social well-being and improves the overall quality of life for all living things. To address the economic and social components of that balance, SOLEC began the development of Societal indicators in 1998. This group of indicators measures human activities and human responses to ecosystem pressures. The scope and structure of the Societal indicator group has continued to evolve over the last 4 years.

In 2000, a subset of societal indicators was proposed and is now known as Societal Response indicators (previously called stewardship indicators). The current set of societal response indicators is the result of a generous input of ideas, information and time by many stakeholders representing all areas within the Great Lakes basin. As with all indicators in the Great lakes suite, the Societal Response indicators will continue to evolve as new ideas are developed and as new information becomes available.

### Societal Indicators and SOLEC

The vision of SOLEC and the related Great Lakes Water Quality Agreement is to "restore and maintain the chemical, physical, and biological integrity" of the waters of the Great Lakes Basin Ecosystem. The activities associated with daily life and the normal functions of society in the Great Lakes region have a significant impact on the health and sustainability of the ecosystem.

The framework for the Great Lakes indicators contains three main groups: Geographic Zones, Issues and Crosscutting (see section 1 of this paper). Within the Issues group, the Societal suite of indicators represents the interconnections between natural environment systems and socio-economic systems (i.e. economic, institutional, community). This group of indicators is designed to measure the health of the Great Lakes ecosystem with respect to pressures imposed on the ecosystem as a result of daily functioning of human environments.

Three categories of indicators comprise the Societal suite, they are: Urban Issues, Socio-Economics and Societal Response. Societal Response indicators measure the human activities that affect ecosystem health, from both a human and natural environment perspective.

Collectively, the Societal suite provides integrated, science-based information on the health of the socio-economic system and the ecosystem as a whole. This information will strengthen decision-making and facilitate effective management programs with the Great Lakes ecosystem; thereby, improving the health of both socio-economic systems and natural environment systems.

Indicators related to the First Nations perspective on ecosystem health will help to complete the Societal Response indicator set. These indicators will be developed in partnership with First Nations communities in the Great Lakes.

### Defining Societal Response within SOLEC

Following the model used for the rest of the Great Lakes indicator suite, the Societal indicator suite is divided into a pressure, state and human activity (response) framework. As already mentioned, Societal Response indicators represent the human response component of the framework within the Societal group. These indicators measure human response to the ecosystem pressures defined within the Societal indicator suite as well as human response to pressures identified in the geographic zones group.

Human activity (response) indicators are measurable and quantifiable values that are designed to represent society's commitment to ecosystem health. Each indicator assesses voluntary activities within society that invoke positive change in the health of the Great Lakes system. These indicators focus on measuring individual actions to mitigate, adapt to or prevent human induced negative impacts on the environment and to halt or reverse environmental damage already inflicted.

Based on feedback obtained in 2001, the human response indicators are divided into three sectors of society. These sectors enable targeted evaluation of the unique role of the household/community, institutional and commercial/industrial sectors within the ecosystem. Combined with the other Societal pressure and state indicators, the Societal Response indicators will allow decision-makers and managers to objectively address progress toward shared governance and community participation, and ultimately, sustainability.

### Indicator Selection Process

At the SOLEC 2000 conference, 19 Societal indicator descriptions were presented for review. Within those 19 indicators, 6 indicators were specifically targeted toward Societal Response. Considerable feedback from the conference and other activities was incorporated into the indicators selection process.

Under the Societal group, state/pressure indicators have been modified only slightly since SOLEC 2000. Due to their relative importance in measuring progress toward an improved environmental state and a more sustainable Great Lakes ecosystem, more substantial changes are now being proposed within the Societal Response indicator set. As part of the Societal Response indicator development process, potential indicators have been reviewed by an expert panel, by participants in a workshop held in October 2001 and by participants in an on-line indicator evaluation survey.

More than 55 indicators have been suggested as Societal Response indicators. Recent efforts to refine the indicator set to a comprehensive, yet more manageable size have occurred in 6 stages, these include:

STAGE 1: Inventory of all the feedback related to the Societal Responsibility indicators and any additional indicator suggestions.

STAGE 2: Evaluation of indicator feedback to assign status (keep, hold, revise, combine, delete) based on the indicator criteria of necessary, feasible, understandable and sufficient. Re-evaluation of the relationship between Societal Response indicators and other SOLEC indicators.

STAGE 3: Revision of the list of Societal Response indicators and incorporation of the list into an evaluation matrix. Division of indicators into three sectors: individual/community, institutional and industrial.

STAGE 4: Collection of additional input/feedback from the Societal indicators expert panel and other interested parties.

STAGE 5: Research on data availability and indicator measures for the indicators with the most potential.

STAGE 6: Draft of potential indicator descriptions. Contact experts related to each indictor to assist with indicator descriptions.

All stages are iterative and new input will continually refine the indicator suite.

Proposed Societal Response Indicators

Based on the results of the 6-stage indicator selection process, 11 potential indicators and their descriptions are being proposed at SOLEC 2002. The indicators are categorized into household/community, industrial/commercial and institutional sectors. Two of these indicators also have a sample report that follow their descriptions. These indicators are: Commercial / Industrial Eco-Efficiency and Cosmetic Pesticide Controls.

*Household/Community*

Household Stormwater Recycling

This indicator will assess the level of public awareness and concern for the environmental consequences of stormwater runoff. Number of households participating in municipal stormwater recycling programs such as rain barrel, green roof and downspout disconnect programs. A complementary measure is the number of household stormwater recycling programs provided by local government.

Community Engagement in Great Lakes Protection and Decision-Making
(revised from indicator #3513)

This indicator will assess the extent of community involvement in Great Lakes activities. It will be an enumeration of membership in community-based groups that engage Great Lakes residents and First Nations in the planning, protection and overall decision-making activities related to the Great Lakes and their tributaries.

Household Solid Waste Minimization

This indicator will assess household participation in solid waste minimization programs (i.e. proportion of generated waste that is diverted from landfill or incineration).

*Commercial/Industrial*

Commercial / Industrial Environmental Management Systems (EMS)

This indicator will assess the level of commitment, on the part of industries and businesses in the Great Lakes ecosystem, to documenting and reducing environmental impacts. It will track the number of organizations in the Great Lakes ecosystem that have adopted environmental management systems such as ISO 14001.

Commercial / Industrial Eco-Efficiency

This indicator will assess the commercial / industrial sector response to pressures imposed on the ecosystem as a result of production processes and service delivery. It will measure the proportion of the 25 largest employers in the basin that report eco-efficiency measures and implement eco-efficiency strategies.

*Institutional*

Municipal Wastewater Treatment

This indicator will assess the scale and scope of municipal wastewater treatment. It will measure the proportion of the population served by municipal sewage treatment facilities, percent of collected wastewater that is treated and the level of municipal treatment provided (primary, secondary, tertiary and/or advanced treatment technologies).

Cosmetic Pesticide Controls

This indicator will assess the number of municipalities in the Great Lakes basin that have banned pesticides from household/community use. It will measure the willingness of local governments and their constituencies to improve community and ecosystem health by taking a proactive step to reduce toxic contaminant exposure.

Taxes on Energy / CO2

This indicator will measure the economic incentives (i.e. environmentally related taxes) that are in place by the state/provincial and federal governments of the Great Lakes basin. As economic incentives, these taxes serve to curb the use of fossil fuels by energy consumers, thereby reducing air emissions.

Environmental Education

This indicator will reveal the amount of environmental and sustainability education currently being incorporated into elementary, secondary and post-secondary curricula, thereby suggesting a link between education and environmental awareness.

Financial Resources Allocated to Great Lakes Programs

Indicator ID #8140

This indicator will track the total amount of dollars spent on an annual basis by state/provincial agencies and non-governmental organizations in each of four areas: Great Lakes research, monitoring, restoration, and protection (including within nearshore lands).

*Note: this indicator is not being revised, it's just being moved into this grouping.*

*Crosscutting*

Vehicle use

This indicator will assess the amount and trends in vehicle use in the Great Lakes basin by measuring number of vehicle miles traveled, number of licensed vehicles and perhaps, fuel consumed in the Great Lakes basin.

4b. Descriptions of the proposed new indicators

Household Stormwater Recycling
New Indicator

*Measure*
Number of households participating in municipal stormwater recycling programs such as rain barrel, green roof and downspout disconnect programs. A complementary measure is the number of household stormwater recycling programs provided by local government.

*Purpose*
To assess the level of public awareness and concern for the environmental consequences of stormwater runoff.

*Ecosystem Objective*
To reduce the pressures induced on the ecosystem as a result of stormwater surges and urban runoff to rivers and lakes within the ecosystem.

*Endpoint*
Thirty percent (or greater) of households participating in stormwater recycling programs in all municipalities within the Great Lakes ecosystem.

*Features*
Stormwater runoff has a significant impact on the water quality of streams, rivers and lakes in the Great Lakes ecosystem. Ecosystem consequences of stormwater run off include increased erosion and flooding, and higher concentrations of contaminants and bacteria. The impact of stormwater in urban areas served by combined sewers is especially significant, due to the effects of combined sewer overflows. This indicator presents trends in community participation in municipal stormwater recycling programs, which reduce the pressure that stormwater runoff has on the ecosystem. Households alone cannot resolve the issues that arise from stormwater runoff; however, this indictor recognizes the significant role that the community plays in stormwater management. By monitoring municipal programs, information is also obtained about the extent of municipal stormwater recycling programs in the basin.

*Illustration*
This indicator will be displayed as a graphic of base-year participation in household stormwater recycling programs to current participation rates. Comparison tables of participation rates and number of municipal stormwater recycling programs amongst urban centers in the Great Lakes region may also be included.

*Limitations*
By focusing on municipal programs, this indicator will not measure stormwater recycling efforts conducted outside municipal programs. While information is widely available, there is no aggregated data source for household stormwater recycling. This indicator is most relevant to households of single-family homes, since many households in multi-family buildings would have limited ability to recycle stormwater.

*Interpretation*
As the number of stormwater recycling programs increase and more households participate, the ecosystem stress caused by stormwater will decrease. Increasing participation rates

indicate a wider public awareness and support for reducing stormwater impacts on the Great Lakes ecosystem.

*Comments*
Descriptions of municipal stormwater management programs are widely available on municipal websites. Expansion of this indicator could also examine greywater recycling efforts, though data in this area are very limited.

*Unfinished Business*

*Relevancies*
Indicator type: response
Environmental Compartment: water
Related issues: water quality, human health, contaminants, water use, land use
SOLEC Groupings: societal response – household/community
GLWQA Annex(es): 2: LaMPs/RAPs/BUIs, 12: Persistent toxic substances, 13: Non-point sources, 17: Res. & Devel.
IJC Desired Outcome(s): 1: Fishability, 2: Swimmability, 3: Drinkability, 4: Healthy Humans, 6: Biological Integrity and Diversity, 7: Virt. Elim. PTS
GLFC Objectives:
Beneficial Use Impairment(s): 1: F&W Consumption, 9: Drinking Water, 10: Beach Closings, 11: Aesthetics

*Last Revised*
July 17, 2002

Community Engagement in Great Lakes Protection and Decision-Making
(Revised from Indicator #3513)

*Measure*
An enumeration of membership in community-based groups that engage Great Lakes residents, including Native (First Nation/Native American) Communities, in the planning, protection and overall decision-making activities related to the Great Lakes and their tributaries. Specific measures include total number of members, basin location and group type. An additional component is the number of activities that include Native perspectives.

Enumeration of all community groups in the Great Lakes is a substantial task, but a strong proxy for measuring community engagement and reducing the resource intensity of this indicator is to conduct a census of land trust agencies.  Progress achieved by land trust activities is easily quantified by tabulating the number of acres preserved. Watershed councils are another particularly relevant group to act as an indicator of community engagement, given their geographic focus. The proportion of Great Lakes basin watersheds and sub-watersheds covered by watershed groups is a potential measure of the breadth watershed council.

*Purpose*
To assess the extent of community involvement in Great Lakes activities and organizations as a measure of community interest and sense of responsibility toward the health and sustainability of the Great Lakes.

*Ecosystem Objective*
Continuing programs supporting protection of the Great Lakes and a sense of community responsibility toward the sustainability of the Great Lakes ecosystem. A critical mass of local support for partnerships responsible for setting and maintaining ecosystem health and integrity in places throughout the Great Lakes basin.

*Endpoint*
Increasing trends of community engagement, by both Native and Non-native communities, in Great Lakes protection and decision-making activities over time.

*Features*
Broad-based community engagement is at the heart of sustainability.  In order to ensure a sustainable Great Lakes ecosystem, active engagement of Great Lakes community members is required.  This indicator measures the trends in citizen involvement and engagement.  By measuring citizen involvement, a sense of community understanding and concern for ecosystem health may also be inferred. Membership in government agency led community-based groups can help to assess government effort to promote civic engagement.

*Illustration*
Graphs, charts and narrative description illustrating the number of residents associated with organizations, programs and projects involved in Great Lakes planning, protection and overall decision-making activities.  Illustrations should be broken down by basin and by type of group.

*Limitations*
Some definition and interpretation is required to determine the parameters for organizations in Great Lakes planning, protection and overall decision-making activities. This indicator

does not necessarily provide information on the diversity of membership within the organizations nor does it provide information as to extent of participation. Multiple memberships in different groups involving the same individual prevent calculation of absolute numbers of participants as a percentage of total basin population, but trends in memberships in Great Lakes organizations over time is still valid.

*Interpretation*
The enumeration of community-based groups and their membership by group type will measure trends in community involvement in ecosystem health activities within the basin. Enumeration of watershed associations can be interpreted as direct activities to improve ecosystem health, whereas membership in Federations, Associations and government initiatives may be more indirect activities.

*Comments*
Data for this indicator may be available from environmental directories and other non-governmental organization directories. Directories are produced by various organizations throughout the basin, including the Great Lakes Information Network. The Land Trust Alliance surveys U.S. land trusts every 10 years. The Ontario Nature Trust Alliance also provides listings of land trusts and Conservancies. Potential groupings for community-based groups include: Clubs/Federations/Societies, Conservancies/Foundations/Institutions, Municipal agency, State/Provincial agency, Federal agency and watershed associations. Alternatively, groupings might also focus on issue areas such as water resources, air quality, land use and protection, and wildlife.

*Relevancies*
Indicator type: response
Environmental Compartment: ecosystem
Related issues: ecosystem health,
SOLEC Groupings: societal response – households/community
GLWQA Annex(es): All
IJC Desired Outcome(s): All
GLFC Objectives: All
Beneficial Use Impairment(s):

*Last Revised*
July 17, 2002

Household Solid Waste Minimization
New Indicator

*Measure*
Participation in solid waste minimization programs (i.e. proportion of generated waste that is diverted from landfill).

*Purpose*
To infer the level of societal response to ecosystem pressures related to household waste generation in the community, by measuring waste minimization efforts.

*Ecosystem Objective*
To reduce the pressures induced on the ecosystem by solid waste and further progression toward sustainable development in the Great Lakes.

*Endpoint*
Full participation (100%) in solid waste minimization programs and declining trends in the proportion of waste landfilled or incinerated.

*Features*
North Americans are one of the largest producers of solid waste in the world. Solid waste deposited or incinerated leaves a residue on the land and contaminants can be redistributed by air and water. Solid waste is also a major source of methane, a strong greenhouse gas and contributor to global climate change. This indicator is a measure of society's response to the pressures that solid waste places on the ecosystem and will potentially identify areas where expansion of waste minimization efforts are needed most. Solid waste minimization activities goes beyond recycling by including reduce and reuse activities, which generally have a greater impact on ecosystem health.

*Illustration*
This indicator will be displayed as a graphic of the proportion of waste that is diverted from landfill - broken down by material type. A second graphic will display the proportion of waste that is diverted from landfill, broken down by waste minimization activity. Participation in solid waste minimization efforts will be measured over time.

*Limitations*
Though most municipalities produce waste generation and minimization information, it will require considerable effort to collect all the information, given the number of municipalities around the Great Lakes. Waste minimization can occur by a variety of means, not all of which are well documented. Depending on data availability, recycling and composting may have to be used as a proxy for all waste minimization efforts, however, such a proxy does not take into account reduce and reuse activities. Waste measurement procedures vary by municipality and therefore caution must be used when aggregating data.

*Interpretation*
By examining all waste minimization activities, this indicator not only looks at participation in recycling, but also examines efforts to reduce waste generation and to reuse materials. This indicator provides some insight into the level of responsibility that society feels toward the impacts of waste deposition.

*Comments*
This indicator should be examined in conjunction with the solid waste generation indicator (#7060) that measures the current state of waste generation. With increasing economic activity, waste generation increases, despite increased recycling activities. Therefore, waste minimization activities need to be weighed against waste generation indicators.

*Relevancies*
Indicator type: response
Environmental Compartment: land
Related issues: waste generation; land use, hazardous waste, wastewater treatment, climate change, contaminants
SOLEC Groupings: societal response
GLWQA Annex(es): 12: Persistent toxic substances
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objectives:
Beneficial Use Impairment(s):

*Last Revised*
July 18, 2002

Commercial / Industrial Environmental Management Systems (EMS)
New Indicator

*Measure*
Number of organizations in the Great Lakes ecosystem that have adopted environmental management systems such as ISO 14001.

*Purpose*
To infer the level of commitment, on the part of industries and businesses in the Great Lakes ecosystem, to documenting and reducing environmental impacts.

*Ecosystem Objective*
To reduce the environmental pressures induced on the Great Lakes ecosystem as a result of materials production and business operations.

*Endpoint*
All medium to large scale industries within the basin participating in voluntary efforts to record and reduce their environmental impact.

*Features*
Environmental Management Systems are a voluntary framework for use by organizations interested in identifying and addressing the significant environmental aspects and related impacts of its activities, products and services. ISO 14001 and other environmental management systems can help organizations to identify and implement management activities in the process toward more sustainable materials production and business operations. The number of environmental management certifications within the basin is a good and easy-to-understand indicator of the region's advancement in voluntary environmental agreements.

*Illustration*
This indicator will be displayed as a chart of the number of EMS certifications within each sector of the economy (using census classifications). Categorization of organization size will also be included where possible. This indicator can be recorded as a time series or as a comparison of current number of certifications to a baseline year at some point in the past.

*Limitations*
While ISO 14001 is one common environmental management system, there are a variety of other systems on the market that are even more widely used. Significant time would be required to collect information on all EMS systems and not all systems are comparable. As a voluntary action in which organizations set their own goals, Environmental Management Systems do not directly measure the scale and scope of environmental protection or mitigation on the part of the participating organization.

*Interpretation*
The number of certified organizations can provide some insight into the level of commitment to ecosystem health held by industries or businesses in the Great Lakes and can be compared with national statistics or international certification numbers.

*Comments*
This indicator should be examined in conjunction with other measures of industrial/commercial performance such as use of product lifecycle measures. Data can be collected from organizations such as the Canadian Standards Council and trade organizations. The most

feasible approach to data collection is to contact trade associations for each of the economic sectors used by census agencies. Many trade agencies keep records of companies with environmental management systems. Although this would not be a comprehensive list it would provide a indicator of trends in the use of Environmental Management Systems.

*Relevancies*
Indicator type: response
Environmental Compartment: crosscutting – air, land, and water
Related issues: industrial pollution, contaminants, toxic substances, human health
SOLEC Groupings: societal responsibility – industrial/commercial
GLWQA Annex(es): 3: Phosphorus, 6: Shipping/Pollution, 12: Persistent toxic substances, 14: Contaminated sediments, 15: Airborne toxic substances
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances, 8: Excess Phosphorus, 4: Healthy Humans, 5: Economic viability
GLFC Objectives:
Beneficial Use Impairment(s): All

*Last Revised*
July 16, 2002

Commercial / Industrial Eco-Efficiency Measures (description)
New Indicator

*Measure*
Proportion of the 25 largest employers in the Great Lakes basin that track and report on eco-efficiency measures (net sales, quantity of goods produced, energy consumption, material consumption, water consumption, greenhouse gas emissions, ozone depleting substances). Data will also be collected on eco-efficiency strategies implemented related to each of the following success factors of eco-efficiency (as developed by the World Business Council on Sustainable Development): material intensity of goods and services, energy intensity of goods and services, toxic dispersion, material recyclability, and sustainable use of renewable resources (material durability).

*Purpose*
To assess the commercial/industrial sector response to pressures imposed on the ecosystem as a result of production processes and service delivery.

*Ecosystem Objective*
To foster healthy, sustainable economic productivity, without compromising environmental and societal health. The first Antwerp Workshop on Eco-efficiency (November, 1993) stated that eco-efficiency is 'reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the earth's estimated carrying capacity'. Reaching this target is consistent with economic, social and environmental sustainability objectives within the Great Lakes basin.

*Endpoint*
100% of the 25 largest employers report publicly on eco-efficiency measures and 100% of the 25 largest employers in the basin have implemented specific eco-efficiency strategies to:
1) reduce the material intensity of goods and services,
2) reduce the energy intensity of goods and services,
3) reduce toxic dispersion,
4) enhance material recyclability; and,
5) maximize sustainable use of renewable resources.

*Features*
Eco-efficiency is founded in the sustainable development principle of integration of economic growth and environmental improvement. Activities associated with eco-efficiency not only reduce stress on the ecosystem, but also emphasize value creation for a stronger economy; the vision of eco-efficiency is to 'produce more from less'. This indicator has the benefit of capturing a wide range of activities that make goods and services production more sustainable. It has the additional feature of being applicable to all economic sectors. By tracking commercial and industrial eco-efficiency activities, it is possible to assess the level to which corporate behavior supports a sustainable Great Lakes ecosystem.

*Illustration*
This indicator will be displayed as a table of the proportion of the 25 largest employers in the basin that measure eco-efficiency and have adopted eco-efficiency strategies.

*Limitations*
There is no single data source for eco-efficiency activities within the basin and, therefore, it is

necessary to limit the number of organizations surveyed. The 25 largest employers were selected as industry leaders and proxy for assessing commercial/industrial eco-efficiency measures. This indicator should not be considered a comprehensive evaluation of all the activities of the commercial/industrial sector, particularly small-scale organizations. Typically, eco-efficiency activities are more widely applied by larger organizations and require longer time scales before they are widely adopted by smaller-scale operations.

*Interpretation*
This indicator can be used to monitor progress toward more responsible goods and services production and a stronger, more sustainable Great Lakes economy.

*Comments*
The World Business Council for Sustainable Development and the World Resources Institute produce extensive resources related to eco-efficiency. Trade organizations are also a good data source. Employer lists are available from local chambers of commerce and InfoUSA, Omaha, Nebraska.

*Relevancies*
Indicator type: response
Environmental Compartment: cross-cutting
Related issues: waste generation, energy use, water use, vehicle use
SOLEC Groupings: societal responsibility – commercial industrial
GLWQA Annex(es): 3: Phosphorus, 6: Shipping/Pollution, 8: Facilities Discharges, 10: Hazardous Polluting Substances, 12: Persistent toxic substances, 14: Contaminated sediments, 15: Airborne toxic substances, 11: Monitoring
IJC Desired Outcome(s): All
GLFC Objectives:
Beneficial Use Impairment(s): All

*Last Revised*
July 15, 2002

Commercial / Industrial Eco-Efficiency Measures (sample report)
New Indicator

Assessment: Unable to make an assessment until historical trend data is available. This is the first time this indicator has been measured.

*Purpose*
This indicator assesses the institutionalized response of the commercial/industrial sector to pressures imposed on the ecosystem as a result of production processes and service delivery. It is based upon the public documents produced by the 25 largest employers in the basin that report eco-efficiency measures and implement eco-efficiency strategies. The 25 largest employers were selected as industry leaders and proxy for assessing commercial/industrial eco-efficiency measures. This indicator should not be considered a comprehensive evaluation of all the activities of the commercial/industrial sector, particularly small-scale organizations, though it is presumed that many other industrial/commercial organizations are implementing and reporting on similar strategies.

*Ecosystem objective*
The goal of eco-efficiency is to deliver competitively priced goods and services that satisfy human needs and increase quality of life, while progressively reducing ecological impacts and resource intensity throughout the lifecycle, to a level at least in line with the earth's estimated carrying capacity[1]. In quantitative terms, the goal is to increase the ratio of the value of output(s) produced by a firm to the sum of the environmental pressures generated by the firm[2].

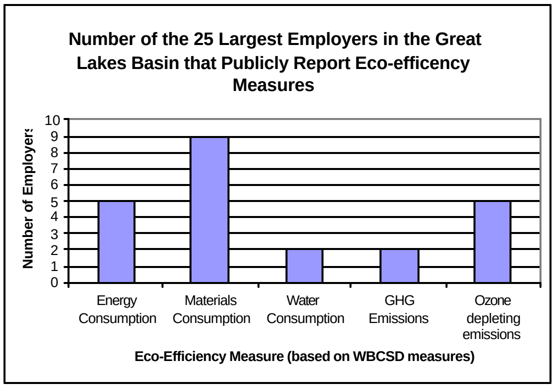
*State of the Ecosystem*
Efforts to track eco-efficiency in the Great Lakes basin and in North America are still in the infancy stage. This is the first assessment of its kind in the Great Lakes region. It includes twenty-five of the largest private employers, from a variety of sectors, operating in the basin. Participation in eco-efficiency was tabulated from publicly available environmental reporting data from 10 Canadian companies and 14 American companies based in (or with major operations in) the Great Lakes.

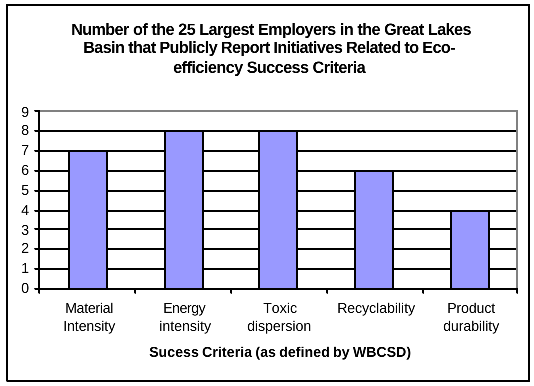
Tracking of eco-efficiency indicators is based on the notion: "what is measured is what gets done". The evaluation of this indicator is conducted by recording presence/absence of reporting related to performance in 7 eco-efficiency reporting categories (net sales, quantity of goods produced, material consumption, energy consumption, water consumption, greenhouse gas emissions, emissions of ozone depleting substances)[3]. In addition, the evaluation includes an enumeration of specific initiatives that are targeted toward one or more of the elements of eco-efficiency success (material intensity, energy intensity, toxic dispersion, recyclability and product durability)[4].

Of the 24 companies surveyed, 10 reported publicly (available online or through customer service inquiry) on at least some measures of eco-efficiency. Energy consumption and, to some extent, material consumption were the most commonly reported measures. Of the 10 firms that reported on some elements of eco-efficiency, 3 reported on all 5 measures.

More companies, 19 (76%) of the 25 companies surveyed, reported on implementation of specific eco-efficiency related initiatives. 2 companies reported activities related to all 5 success areas. Reported initiatives were most commonly targeted toward improved recycling and improved energy efficiency.

Overall, companies in the manufacturing sector tended to provide more public information on environmental performance than the retail or financial sectors. At the same time, nearly all firms expressed a commitment to reducing the environmental impact of their operations. A select number of companies, such as Steelcase Inc. and General Motors in the U.S.A. and Nortel Networks in Canada, have shown strong leadership in comprehensive, easily accessed, public reporting on environmental performance. Others, such as Haworth Inc. and Quad/Graphics, have shown distinct creativity and innovation in implementing measures to reduce their environmental impact.




The concept of eco-efficiency was defined in 1990 and was not widely known until several years later. Specific data on commercial/industrial measures are only just being implemented; therefore, it is not yet possible to determine trends in eco-efficiency reporting. In general, firms appear to be working to improve the efficiency of their goods and service delivery. This is an important trend as it indicates the growing ability of firms to increase the quantity number of goods and services produced for the same or a lesser quantity of resources per unit of output.

While one or more eco-efficiency measures are often included in environmental reporting, only a few firms recognize the complete eco-efficiency concept. Many firms recognize the need for more environmentally sensitive goods and services delivery; however, the implementation of more environmentally efficient processes appears narrow in scope. These observations indicate that more could be done toward more sustainable goods and services delivery.

*Future Pressures*
Eco-efficiency per unit of production will undoubtedly increase over time, given the economic, environmental and public relations incentives for doing so. However, as Great Lakes populations and economies grow, quantity of goods and services produced will likely increase. If production increases by a greater margin than eco-efficiency improvements, then the overall commercial/industrial environmental impact will continue to rise. Absolute reductions in the sum of environmental pressures are necessary to deliver goods and services within the earth's carrying capacity.

*Future Action*
The potential for improving the environmental and economic efficiency of goods and services delivery is unlimited. To meet the ecosystem objective, more firms in the commercial/industrial sector need to recognize the value of eco-efficiency and need to monitor and reduce the environmental impacts of production.

*Further Work Necessary*

By repeating this evaluation at a regular interval (2 or 4 years) trends in industrial/commercial eco-efficiency can be determined. The sustainability of goods and service delivery in the Great Lakes basin can only be determined if social justice measures are also included in commercial/industrial sector assessments. The difficulty in assessing the impacts of social justice issues precludes them from being included in this report, however, such social welfare impacts should be included in future indicator assessment.

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*Acknowledgments*

Author: Laurie Payne, LURA Consulting. Contributors: Christina Forst, US EPA, and Dale Phenicie & George Kuper, Council of Great Lakes Industries. Tom Van Camp and Nicolas Dion of Industry Canada provided several data resources. Many of the firms surveyed in this report also contributed environmental reports and other corporate information. Chambers of commerce in many states and provinces around the Great Lakes provided employment data.

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[i] World Business Council for Sustainable Development, Eco-efficient Leadership for Improved Economic and Environmental Performance (Geneva, 1996), p. 4.

[ii] Adapted from Organization for Economic Cooperation and Development (OECD), Environment Policy Committee, Environment Directorate, Eco-Efficiency: Environment Ministerial Steering Group Report, (Paris, March 1998), p. 3.

[iii] World Business Council for Sustainable Development, Eco-efficiency. Creating more value with less impact. (2002).

[iv] World Business Council for Sustainable Development, Eco-efficiency. Creating more value with less impact. (2002) p. 15.

Municipal Wastewater Treatment
New indicator

*Measure*
Proportion of the population served by municipal sewage treatment facilities, percent of collected wastewater that is treated and level of municipal treatment provided (primary, secondary, tertiary and/or advanced treatment technologies).

*Purpose*
To assess the scale and scope of wastewater treatment as a measure of the relative amount of wastewater contaminants that are entering the waste stream and a measure of municipal commitment to protecting freshwater quality.

*Ecosystem Objective*
To reduce the pressures induced on the ecosystem by insufficiently treated wastewater and further progression toward sustainable development in the Great Lakes.

*Endpoint*
To treat all wastewater to a quality whereby water released back into the ecosystem is cleaner than the background quality of the water body.

*Features*
Chemicals and disease-causing organisms found in insufficiently treated wastewater can threaten public health and the health of other organisms living in the Great Lakes ecosystem. This indicator measures progress toward safe and innocuous wastewater releases to the environment. In particular, this indicator provides information on how well local governments are managing wastewater generated in their communities. Measuring the level of treatment used provides additional information on the quality of water returned to the environment. Measures of percent of population connected to municipal treatment facilities has also been used as an indicator of urban sprawl, since developments in greenfield areas may not be supported by municipal infrastructure services.

*Illustration*
This indicator will be displayed as two time-series of graphs: percent of wastewater treatment vs. wastewater collected and percent of population connected to sewage treatment systems. The level of treatment will be shown in a pie chart representing each treatment type.

*Limitations*
Though most municipalities produce wastewater treatment data, it may require considerable effort to collect all the information, particularly in smaller or more rural communities. Wastewater treatment technologies vary by municipality and, in some cases, may be difficult to classify.

*Interpretation*
This indicator can be used to monitor progress toward more comprehensive wastewater treatment over time. Data collected can also used to make comparisons between regions within the Great Lakes ecosystem.

*Comments*
This indicator should be examined in conjunction with the percent of greywater recycled indicator, that measures the current state wastewater reuse and efficiency of treatment.

Further research related to this indicator may include examination of industrial wastewater treatment, programs to measure the efficiency of wastewater treatment facilities and pricing of wastewater treatment services.

*Relevancies*
Indicator type: response
Environmental Compartment: water
Related issues: waste generation, water quality, human health contaminants
SOLEC Groupings: societal responsibility - institutional
GLWQA Annex(es): 3: Phosphorus, 8: Facilities, 10: Hazardous Pollutants, 12: Persistent toxic substances, 14: Contaminated Sediments
IJC Desired Outcome(s): 1: Fishability, 2: Swimmability, 3: Drinkability, 4: Healthy Humans, 7: Virtual elimination of inputs of persistent toxic substances, 8: Excess phosphorus
GLFC Objectives:
Beneficial Use Impairment (s): 1: F&W Consumption, 2: Tainting, 3: F & W Populations, 4: Tumours, 5: Deformities, 8: Eutrophication, 9: Drinking water, 10: Beach Closings, 11: Aesthetics

*Last Revised*
July 15, 2002

Cosmetic Pesticide Controls (description)
New Indicator

*Measure*
In the wake of the Canadian Supreme Court ruling upholding the right of municipalities to ban certain chemicals from residential lawns and community use, this indicator seeks to measure the number of municipalities invoking such a ban. This, in turn, measures the willingness of local governments to proactively improve community and ecosystem health by reducing contaminant exposure.

*Purpose*
To identify the communities that are invoking a ban on harmful pesticides, to explore the reasons for their decision and to raise awareness of this new policy in other communities in Canada as well the US that have not yet imposed such restrictions.

*Ecosystem Objective*
To reduce the amount of contaminants in the ecosystem. To prevent further contamination of land, waterways and degradation of human health.

*Endpoint*
We look towards an endpoint of full bi-national participation in the control of cosmetic pesticides by all municipalities in the basin, although this may take a long period of time. Until then, this indicator may be more useful to reflect a positive trend whose endpoint may sharpen when revisited in 4 or 8 years.

*Features*
The effects of pesticide exposure include poisoning, eye damage, disruption of the endocrine system and respiratory ailments. These effects are exacerbated in children. Exposure to pesticides may occur via direct contact through improper use, consumption through the residual pesticide on food, and release into the environment from improper storage or disposal. It was for these and other reasons that several municipalities in Canada banned the use of pesticides on public land and private property. The time scale of this policy has been relatively short, as the policy is a new enactment, and the geographic scale is increasing from Quebec, to Ontario and the United States.

*Illustration*
This indicator will be a numerical ratio of municipalities that do have bans in place out of the total number of municipalities in the basin. In addition to ratios, maps may be used. A chart for each country may display the municipalities that have banned the use of pesticides as of 2002.

*Limitations*
The utility of this indicator at this time may be slightly compromised by the fact that since June 2001, only a select number of municipalities in Canada have begun to enact pesticide bans and even fewer in the U.S. This concept represents relatively new environmental policy that is becoming more widely implemented as more municipalities consider it.

*Interpretation*
To place this indicator in better context, it is helpful to refer to the total amounts of non-agricultural pesticides or fertilizers used on Great Lakes basin household lawns and public community areas each year. US and Canadian data for this give an idea as to the millions of

pounds/kilograms in question, and are available as a supplement to the "Illustration" section of this indicator description.

*Comments*
A further measurement of the extent to which alternatives to chemical pesticides (Integrated Pest Management) are used in all urban centers and municipalities could be incorporated into this study.

*Unfinished Business*
Comprehensive research is needed in order to get accurate updated pesticide usage and policy information for every municipality in the Great Lakes basin.

*Relevancies*
Indicator type: Response
Environmental Compartment: Land, water
Related Issues: Green planning process, indicator #7053, pest management, agriculture
SOLEC Groupings: societal responsibility-institutional
GLWQA Annex(es): 12: Persistent Toxic Substances, 13: Pollution from non-point sources,16: Pollution from Contaminated Groundwater
IJC Desired Outcome(s): 4: Healthy human populations, 7: Virtual elimination of inputs of persistent toxic substances, 9: Physical environmental integrity
GLFC Objective:
Beneficial Use Impairment(s):

*Last Revised*
August 13, 2002

Cosmetic Pesticide Controls (sample report)
New Indicator

Assessment: Unable to make an assessment until historical trend data is available. This is the first time this indicator has been measured.

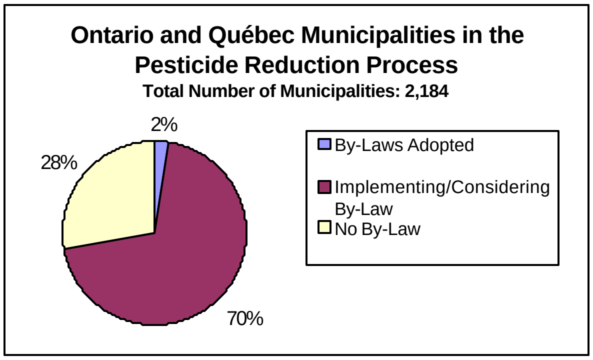
*Purpose*
This indicator will track the number of and trend among municipalities in the Great Lakes Basin that have implemented by-laws or ordinances restricting the cosmetic use of pesticides. It will indirectly measure and identify the willingness of local governments to proactively improve community and ecosystem health by reducing contaminant exposure to residents and the ecosystem.

*Ecosystem Objective*
The objective is to reduce the amount of contaminants in the Great Lakes ecosystem, particularly since pesticide contamination in drinking water can post a threat to human health. Ultimately, the objective is to prevent further contamination of land, waterways and degradation of human health and wildlife.

*State of the Ecosystem*
The effects of pesticide exposure may include disruption of the endocrine, reproductive, neurological and immune systems, carcinogenic effects, eye damage, poisoning and respiratory ailments. Children are even more susceptible to dangerous effects of exposure, which may occur via direct contact through improper use, consumption through the residual pesticide on food, and release into the environment from improper storage or disposal. Once applied to lawns, pesticides may migrate to air, soil, groundwater and surface water thereby contaminating the ecosystem and its dependents. For the Great Lakes Basin, this migration effect could cause significant degradations in the quality of drinking water and health of the overall ecosystem.

The municipality of Hudson, Québec, was the first municipality to pass a by-law in 1991 prohibiting the use of cosmetic (purely aesthetic) use of pesticides. When challenged by a lawsuit, the case ultimately went to the Supreme Court of Canada, whose landmark decision in June 2001 ruled that municipalities did have the right to restrict pesticide use on public and/or private property, since "Law-making [is] often best achieved at a level of government that is…closest to the citizens affected…"[5] Following Hudson's example, 45 additional municipalities out of a total of 1,556 in Québec passed similar by-laws restricting the use of pesticides on public lands, private lands, or both. An additional 6 municipalities' pesticide bylaws will be effective as of January 2003. Recently, however, the provincial government of Québec introduced stringent pesticide regulations that all municipalities will now be subject to. As of September 2002, pesticides on the market were banned from all public, semipublic, and municipal green areas in the province. This decision also marked the beginning of a three-year plan to extend the prohibition to the entirety of private and commercial green spaces in the province as well, excluding agricultural lands.

In the province of Ontario, Cobalt was the first and at this time remains the only municipality in Ontario that has definitively passed a bylaw banning the non-essential use of pesticides on all properties within the municipality. The Canadian capital, the City of Ottawa, however, has banned the use of pesticides on public municipal property and will begin the public consultation process in fall 2002 to enact a bylaw that would restrict all cosmetic use of pesticides within the city. Additionally, there are 22 (including Ottawa) out of 628 total municipalities in Ontario that are phasing out pesticide use, and in various stages of public and/or Council deliberation on the passage of a pesticide by-law.




At present, few municipalities in the U.S. Great Lakes Basin have formally enacted restrictions similar to those in the above-described Canadian municipalities; although it is reasonable to expect similar regulations in the U.S. in the near future. A related effort may be seen in the fact that all eight Great Lakes Basin states have adopted some form of legislation to restrict the use of pesticides in schools, from notifying parents when pesticides are being sprayed in public schools to requiring Integrated Pest Management for structural pest control. On a national level, the U.S. EPA has banned certain individual pesticides such as chlorpyrifos, an insecticide sold under the trade name "Dursban", and continues with many initiatives to phase-out use of harmful pesticides.

*Future Pressures*
Increased and sustained use of pesticides will cause further pressure on the ecosystems and potentially cause increased health concerns and contaminated drinking water for residents in the Great Lakes Basin.

*Future Activities*
As a province, Ontario is now also feeling pressure by activists to pass a provincial law as Québec did, to eliminate first the public and then private cosmetic use of pesticides. This initiative should continue to be monitored for updates. Both in the U.S. Congress, as well as the and state and local government levels, initiatives and proposed bills/ordinances for pesticide reductions should continue to be monitored for future adoptions.

*Future Work Necessary*
Because this concept represents relatively new environmental policy, work will need to be done in the future to re-assess current numbers of municipalities that have passed by-laws/ordinances restricting the commercial, cosmetic use of pesticides. Cosmetic pesticide control is gaining significant attention in local environmental policy, and this indicator will likely serve as a reflective trend indicator when revisited in four or eight years. For Canadian communities currently in deliberation or consideration stages of by-law enactment, follow-up will be needed in several years to confirm if a law has passed. Finally, it will be interesting to document if and when the United States adopts similar laws in regards to municipality restrictions. Though yet to be developed, the endpoint of this indicator includes having bi-national participation in pesticide reduction efforts, so that a significant decrease in contaminant levels within the ecosystem is evident.

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US EPA, Office of Pesticide Programs. http://www.epa.gov/pesticides/

*Acknowledgments*
Author: Christina Forst, U.S. EPA. Contributors: Laurie Payne, LURA Consulting/ Environment Canada.

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[5] *114957 Canada Letée (Spraytech, Société d'arrosage) v. Hudson (Town)*, 2001 SCC 40.File No.: 26937

Taxes on Energy and $CO_2$
New Indicator

*Measure*
The number of economic incentives to reduce energy and fossil fuel consumption that are in place by the state/provincial and federal governments of the Great Lakes basin. This will be measured by the amount of tax revenues raised by said governments.

*Purpose*
To determine the effect that economic incentives have on consumption rates of fossil fuels.

*Ecosystem Objective*
To reduce total air emissions, increase air quality and reduce the pressure caused by greenhouse gases such as $CO_2$.

*Endpoint*
A significant increase in the uptake of alternatives (thereby reducing air emissions and other pollution levels) due to the implementation of economic incentives or environmentally related taxes. It is impossible to state an endpoint that reflects unrealistic taxation amounts, though this indicator may serve to reflect a positive trend when revisited again in several years.

*Features*
The economic incentives referred to here are in the form of environmentally related taxes, which are defined by the Organisation for Economic Co-operation and Development (OECD) as “any compulsory, unrequited payment to general government levied on tax-bases deemed to be of particular environmental relevance”. Taxes are “unrequited” in the sense that benefits provided by government to taxpayers are not normally in proportion to their payments. The environmental impact of a tax or levy comes primarily through the impact it has on relative consumer and producer prices of environmentally related goods and services, in conjunction with the relevant price elasticities. The OECD keeps an “Environmentally Related Taxes Database” for the taxes, fees and charges levied in OECD member countries, including the U.S. and Canada, which, for the purposes of developing this topic as an indicator, will be a very useful starting point to this study.

*Illustration*
The OECD has several relevant graphs on their website which can be used as a model to display data from the U.S. and Canada. Revenues raised from some environmentally related tax-bases (including energy, fuel consumption and air emissions) can be displayed in a bar graph. Exact illustrations are to be determined, based on amount of data obtained.

*Limitations*
The information to compile OECD’s database was collected in 1998 and while much of the information was collected directly from the ministries/departments of finance in the respective countries, in some cases information is still lacking. Therefore, the OECD may be a helpful starting place, however more research would need to be done in order to obtain current data. Also, the OECD warns those observing their graphs to review them with caution, as the figures do not (on their own) provide sufficient information to judge the “environmental friendliness” of the tax systems in the countries concerned. For such analyses, a careful examination of the actual data and of additional information describing the economic and taxation structure of each country is required. This same issue would need to be

cautioned against this indicator in our study as well.

*Interpretation*

In order to place this indicator in context, it would be helpful to know what alternatives, if any, the taxpayers have reverted to in the wake of such taxation/incentive. This indicator does support the higher ecosystem objective of reducing air emissions, though sometimes, inadvertently. For example, a tax on fuel oil introduced for purely fiscal reasons may have the same environmental impact as a tax on fuel oil introduced to combat $CO_2$ emissions, to the extent that the tax leads to similar changes in the prices of relevant tax-bases.

*Unfinished Business*

Current and relevant data need to be obtained based on the model that the OECD used.

*Relevancies*

Indicator type: Response
Environmental Compartment: air, land
Related Issues: Mass Transportation #7012, and Vehicle Use (proposed), air quality
SOLEC Groupings: societal responsibility-institutional
GLWQA Annex(es):
IJC Desired Outcome(s): 5: Economic viability
GLFC Objective:
Beneficial Use Impairment(s):

*Last Revised*

August 13, 2002

Environmental Education
New Indicator

*Measure*
The number of elementary schools and secondary schools that incorporate environmental education issues into standard science curricula, as well as a measure of the aptitude/awareness that elementary and secondary students have of environmental issues, based on scores of science achievement tests.

*Purpose*
To explore the relationship between education and the level of commitment to and awareness of environmental issues.

*Ecosystem Objective*
As consumers and therefore producers of waste, living in and among many disrupted, complex ecosystems, members of society should use education and awareness as tools to increase their understanding of all ecosystems in order to improve them by making better and informed decisions.

*Endpoint*
To integrate environmental education into the mainstream of traditional science education curricula in all elementary and secondary schools in the hopes that such efforts will foster an environmentally literate citizenry/society that is well equipped to make conscious decisions and informed choices, as well as be contributory, responsible members of the community.

*Features*
In reality, this indicator's potential scope could go far beyond the formal classroom, as there are many professionals, volunteers and organizations involved in promoting environmental education in a variety of ways including workshops, extracurricular activities, field studies, nature camps/hikes, summer programs and museum classes. News media also play a role in "educating" the public. However, on an academic level, environmental education should not only seek to raise consciousness of important issues, but ask students to consider ways to work together to improve and solve environmental problems. Such awareness helps to develop environmental leaders.

*Illustration*
The level of scholastic achievement in environmental issue areas will be graphically represented in a line or bar graph depending on the data gathered.

*Limitations*
The vast number of schools across two countries that are included under the umbrella of this study make input of data for each individual school difficult to attain. At this stage, only a broader look at science curricula is possible, through available data sources.

*Interpretation*
Though education is one of the most effective vehicles towards greater awareness, in terms of the larger ecosystem goal, it would be difficult to quantitatively correlate the public's specific environmental decisions to concepts or lessons they learned in school. It should be taken into account that other influential factors such as newspaper articles or economic incentives could potentially skew the data.

*Comments*
According to a Roper poll cited on the website of the North American Association for Environmental Education (NAAEE), ninety-five percent of U.S. residents believe environmental education should be taught in schools.

*Unfinished Business*
Further research about the curricula of elementary and secondary level education is needed in order to obtain a complete picture of environmental education as a whole. The study might be expanded to include a measure of university level environmental education as well. Although at this level of education a student chooses to pursue environmental studies and is not required to study them as part of a core curriculum, measuring this would be beneficial because graduates often become environmental leaders. Finally, the NAAEE is currently working with states and provinces to develop an environmental education certification process for primary and secondary teachers, representing a possible future measurement that would be beneficial for more fully implementing this indicator.

*Relevancies*
Indicator type: Response
Environmental Compartment: Cross-cutting: air, land, water
Related Issues: education
SOLEC Groupings: societal responsibility - institutional
GLWQA Annex(es): 17: Research and Development
IJC Desired Outcome(s): 4: Healthy human populations
GLFC Objective:
Beneficial Use Impairment(s):

*Last Revised*
August 13, 2002

Vehicle Use
New Indicator

*Measure*
Amount of vehicle miles traveled. Number of licensed vehicles in the Great Lakes basin. Amount of fuel consumed.

*Purpose*
To assess the amount and trends in vehicle use in the Great Lakes basin and to infer the societal response to the ecosystem stressed caused by vehicle use.

*Ecosystem Objective*
This indicator supports Annex 15 of the Great Lakes Water Qualilty Agreement. An alternative objective is to reduce stress on the environmental integrity of the Great Lakes region caused by vehicle use.

*Endpoint*
Declining trends in automobile dependence and vehicle emissions.

*Features*
Automobiles are the primary contributor to the level of greenhouse gases in the atmosphere. Emissions from vehicle use also contribute contaminants to air and water systems. Automobile oriented development degrades the liveability of urban environments. This indicator assesses the societal response to the well-known consequences of automobile use by measuring trends in vehicle use. This indicator is reported by measuring vehicle miles travelled, amount of fuel consumed, car ownership numbers. Vehicle use measures provide data that is not available from modal split measures including possible trends in trip distance (a proxy for sprawl development) and trends in number of trips taken.

*Illustration*
A chart showing vehicle miles travelled in the basin or amount of fuel consumed over time will best represent this indicator. Graphic representation of this indicator also involves a ratio of vehicle miles travelled to number of licensed vehicles to infer individual automobile use trends.

*Limitations*
This indicator is limited by details such as different sized cars and trucks will emit different levels of emissions. Daily vehicle miles travelled rates may not take into account a lower number of weekend trips. This measure does not separate miles travelled by trip type, such as commercial goods movement, travel to work and home based trips.

*Interpretation*
This indicator can be used as a reference, indicating an improvement in the state of the ecosystem, as well as a community’s commitment towards ecosystem health. Results for this indicator should be interpreted in conjunction with urban development patterns in the basin and indicators in the Urban Issues suite of indicators. Those collected can also be used to compare areas within the Great Lakes region.

*Comments*
This indicator should be measured in conjunction with trends in mass transportation (#7012), which is an alternative to vehicle use. Focusing on automobile use and the current

transportation trends will lead to the establishment of higher levels of air quality and in turn improved human health. Data for this indicator is produced by census agencies and local transportation planning departments.

*Relevancies*
Indicator type: response
Environmental Compartment: crosscutting – air, land, and water
Related issues: mass transit, air quality, urban sprawl, smog
SOLEC Groupings: societal responsibility – household/community
GLWQA Annex(es): 10: Hazardous Pollutants, 13: Non-point sources, 15: Airborne Toxic Substances, 17: Research & Development
IJC Desired Outcome(s): 4: Healthy humans, 5: Economic Viability, 6: Biological Integrity and Diversity, 9: Physical Environmental Integrity
GLFC Objectives:
Beneficial Use Impairment(s): 3: F & W Populations, 9: Drinking water, 14: F&W Habitat

# 5. Agriculture Indicators

Based on feedback received at SOLEC 98 and SOLEC 2000 it has been concluded that one agricultural indicator is insufficient to determine the impact of agriculture on other ecosystem components in the Great Lakes basin. Due to this, two new agriculture indicators are being proposed at SOLEC 2002: Nutrient Management Plans and Integrated Pesticide Management. They both are human activity (response) type indicators as they look at the management of contaminants that can (and have) cause serious problems to the ecosystem.

There is a description for each indicator followed by a sample report. This has been done to help the discussions on the usefulness of each indicator.

## 5b. Proposed New Agricultural Indicators with Examples of Reporting

Nutrient Management (description)
New Indicator

*Measure*
Number of Nutrient Management Plans (NMP) in place. Percentage of Municipalities with Nutrient Management By-law's containing standards for intensive livestock operations.

*Purpose*
To determine the number of Nutrient Management plans and to infer environmentally friendly practices in place, to prevent ground and surface water contamination.

*Ecosystem Objective*
This indicator supports Annexes 2, 3, 11,12 and 13 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 protection of water quality as well as the sustainable future of agriculture and rural development and 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. Nutrient management is managing the amount, form, placement and timing of applications of nutrients for crop uptake and is typically part of an environmental farm management plan. It is expected that more farmers will embrace environmental planning over time.

The Ontario Environmental Farm Plans (EFP) identifies the need for best nutrient management practices. Over the past 5 years significant progress has been made by Ontario farmers, municipalities and governments and their agencies to implement nutrient management planning. Ontario farmers and consultants are attending workshops to assist with the development of nutrient management plans. Each farmer in their EFP may list environmental actions such as these that they intend to take as a result of completing their EFP. These actions however are currently not tracked by any government agency. The EFP was intended to be an education awareness evaluation tool and not to be used to track environmental actions taken. As part of Ontario's Clean Water Strategy, the recently passed Nutrient Management Act (June 2002) will provide for province-wide standards to address the effects of agricultural practices on the environment, especially as they related to land-applied materials containing nutrients. An anticipated requirement of this act will be the tracking of land-applied nutrients by farms and municipalities alike.

Two U.S. programs dealing with agriculture nutrient management are the Comprehensive Nutrient Management Plans (CNMP) developed by USDA and the proposed Permit Nutrient Plans (PNP) under the Environmental Protection Agency's (EPA) National Pollution Discharge Elimination System permit requirements. State's in the U.S. also have additional nutrient management programs.

*Illustration*
for the U.S. portion of the basin the graphic will show the total number of nutrient management plans that are developed expressed as a percentage of the total number of farms in the basin. In Canada the graphic will show the percentage of municipalities with nutrient management by-law's containing standards for intensive livestock operations.

*Limitations*
Presently on the Canadian side (Ontario) Nutrient Management Plans (NMP) are done on a voluntary basis and where municipal by-laws require them to be completed. Due to the fact that NMP's are voluntarily done every plan developed/put into place is not tracked. There are similarities and differences between nutrient management by-laws that reflect local concerns yet highlight the need for standardisation. Such standardisation is proposed in Ontario in the form of province-wide legislation regarding the management of nutrients.

In the United States basin the CNMP's are currently tracked on an annual basis due to the rapid changes in farming operations. This does not allow for an estimate of the total number of CNMP's. EPA will be tracking PNP as part of the State's NPDES program.

*Interpretation*
Having a completed a NMP provides assurance farmers are considering the environmental implications of their management decisions. The more plans in place the better. In the 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*
In 1998 Ontario provincial staff of the Ministry of Agriculture, Food and Rural Affairs (OMAFRA) assisted with the development of a model by-law for municipalities to use. The intent of the model by-law is to promote consistency in by-law development across the province. In many instances these by-laws require that OMAFRA, consultants, or professionals certified by OMAFRA complete third-party review of NMP submitted to support a building permit application. At this time OMAFRA also developed Nutrient Management Plan software (NMAN). This allowed for the consistent preparation of nutrient management plans and conformed to the Ministry's 1998 Nutrient Management Planning Strategy. Some municipalities enforce each nutrient management by-law by inspections performed by employees of the municipality or others under authority of the municipality. Presently in Ontario provincial legislation A Proposed Nutrient Management Act (Bill 81) is before the legislature. If proclaimed, provincial regulations under it would supersede municipal by-laws and make Nutrient Management Plans a legal requirement for all farms. This proposed legislation stipulates the establishment of a computerised NMP registry that would act as a tracking method for nutrient management plans.

In 1997 the USDA's Natural Resources Conservation Service formed a team to revise its Nutrient Management Policy. The final policy was issued in the Federal Register in 1999. In December 2000, USDA published its Comprehensive Nutrient Management Planning Technical Guidance (CNMP Guidance) to identify management activities and conservation practices that will minimize the adverse impacts of animal feeding operations on water quality. The CNMP Guidance is a technical guidance document only; it does not establish regulatory requirements for local, tribal, State, or Federal programs. PNPs are complementary to and leverage the technical expertise of USDA with its CNMP Guidance. EPA is proposing that CAFOs, covered by the effluent guideline, develop and implement a PNP.

*Relevancies*
Indicator Type: human activity
Environmental Compartment(s): land
Related Issue(s): stewardship
SOLEC Grouping(s): land use
GLWQA Annex (es): 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
IJC Desired Outcome(s): 8: Absence of excess phosphorus, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 8: Eutrophication or undesirable algae, 14: Loss of fish and wildlife habitat

*Last Revised*
Aug 17, 2002

Nutrient Management Plans (sample report)
New Indicator

## Purpose

To determine the number of Nutrient Management plans and to infer environmentally friendly practices that help to prevent ground and surface water contamination.

## Ecosystem Objective

This indicator supports Annexes 2, 3, 11,12 and 13 of the GLWQA. The objective is sound use and management of soil, water, air, plants and animal resources to prevent degradation of the environment. The objective of Nutrient Management Planning is to mange the amount, form, placement and timing of applications of nutrients for uptake by crops as part of an environmental farm plan. It is expected that more farmers will embrace environmental planning over time. This results in sustainable agriculture through non-polluting, energy efficient technology and best management practices for efficient and high quality food production.

## State of the Ecosystem

Given the key role of agriculture in the Great Lakes ecosystem, it is important to track changes in agricultural practices that can lead to protection of water quality as well as the sustainable future of agriculture and rural development and 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. The Ontario Environmental Farm Plans (EFP) identifies the need for best nutrient management practices. Over the past 5 years farmers, municipalities and governments and their agencies have made significant progress. Ontario Nutrient Management Planning (NMP) software (NMAN) is available to farmers and consultants wishing to develop/assist with the development of nutrient management plans.

In June 2002 Ontario introduced legislation for (Nutrient Management Act (NM Act) to establish province-wide standards (currently under development) to ensure that all land-applied materials will be managed in a sustainable manner resulting in environmental and water quality protection. It will supercede existing regulatory provisions (municipal by-laws), guidelines and voluntary best management practices. It is anticipated that the NM Act will require standardization, reporting and updating of nutrient management plans through a nutrient management plan registry. To promote a greater degree of consistency in by-law development Ontario developed a model nutrient management by-law for municipalities. Prior to the NM Act, municipalities enforced each nutrient management by-law by inspections performed by employees of the municipality or others under authority of the municipality.

Two U.S. programs dealing with agriculture nutrient management are the Environmental Quality Incentive Program's (EQIP) Comprehensive Nutrient Management Plans (CNMP) developed by USDA and the proposed Permit Nutrient Plans (PNP) under the Environmental Protection Agency's (EPA) National Pollution Discharge Elimination System permit requirements. State's in the US also have additional nutrient management programs. An agreement between the US EPA and USDA under the Clean Water Action plan called for a Unified National Strategy for Animal Feeding Operations.

The total number of nutrient management plans that are developed annually is shown in

Figure 1 for the US portion of the Basin. Figure 2 shows the number of Nutrient Management Plans by Ontario County for the years 1998 – 2000. Until Nutrient Management regulations are put into place in Ontario Nutrient Management Plans (NMP) continue to be done on a voluntary basis except where municipal by-laws require them to be completed. Nutrient Management Plans are not currently tracked except where required by the municipality. There are similarities and differences between municipal nutrient management by-laws that reflect local concerns yet highlight the need for standardisation. Such standardisation will be a part of the regulation development process in Ontario's Nutrient Management Act.

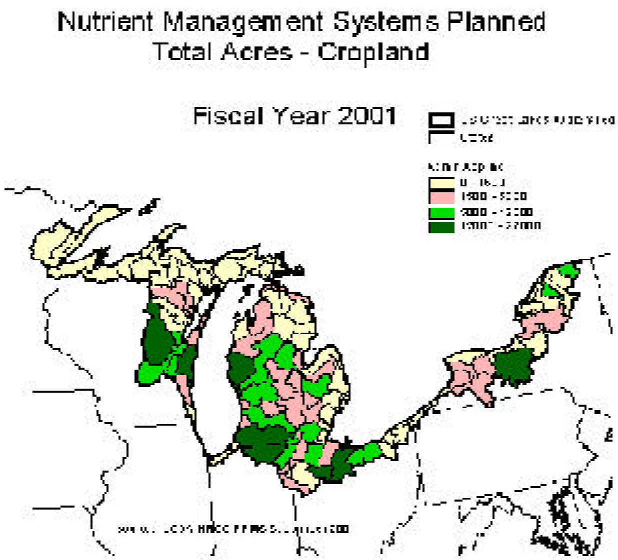


Figure 1. Annual U.S. Nutrient Management Systems Planned for FY 01
(Source: USDA, NRCS, Performance and Results Measurement System)

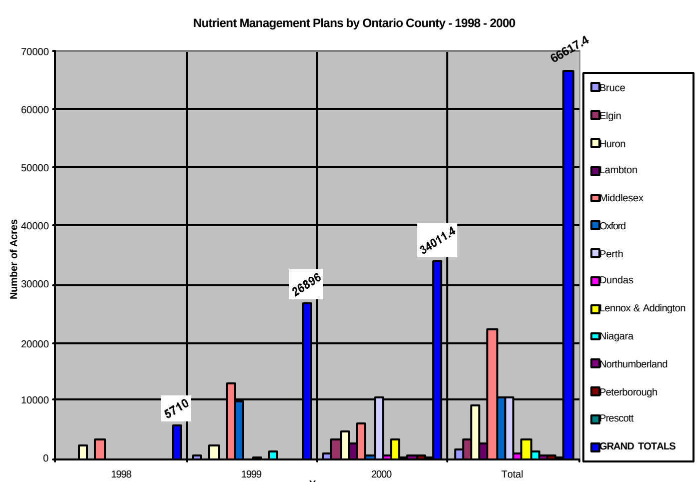


Figure 2. Nutrient Management Plans by Ontario County

In the United States basin the CNMP's are tracked on an annual basis due to the rapid changes in farming operations. This does not allow for an estimate of the total number of CNMP's. EPA will be tracking PNP as part of the Status's NPDES program.

Having a completed a NMP provides assurance farmers are considering the environmental implications of their management decisions. The more plans in place the better. In the 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.

### Future Pressures

As livestock operations consolidate in number and increase in size in the basin planning efforts will need to keep pace with the planning workload and changes in water and air quality standards and technology. Consultations regarding the provincial and U.S. standards and regulations will continue into the near future.

### Future Actions

The new Nutrient Management Act authorizes the establishment and phasing in of province-wide standards for the management of materials containing nutrients and sets out requirements and responsibilities for farmers, municipalities and others in the business of managing nutrients. It is anticipated that the regulations under this act will establish a computerized NMP registry; a tool that will track nutrient management plans put into place. This tool could form a part of the future "evaluation tool box" for nutrient management plans in place in Ontario. The phasing in requirements of province-wide standards for nutrient management planing in Ontario and the eventual adoption over time of more sustainable farm practices should allow for ecosystem recovery with time.

In the U.S. USDA's Natural Resources Conservation Service formed a team to revise its Nutrient Management Policy. The final policy was issued in the Federal Register in 1999. In December 2000, USDA published its Comprehensive Nutrient Management Planning Technical Guidance (CNMP Guidance) to identify management activities and conservation practices that will minimise the adverse impacts of animal feeding operations on water quality. The CNMP Guidance is a technical guidance document and does not establish regulatory requirements for local, tribal, State, or Federal programs. PNPs are complementary to and leverage the technical expertise of USDA with its CNMP Guidance. EPA is proposing that CAFOs, covered by the effluent guideline, develop and implement a PNP.

Acknowledgments
Authors: Ruth Shaffer, and Roger Nanney, USDA, NRCS, Peter Roberts and Jean Rudichuk, OMAF, Guelph, Ontario.

Integrated Pest Management (description)
New Indicator

*Measure*
The acres of USDA recorded Pest Management Plans developed and applied in the U. S. Great Lakes basin. Report the numbers of farmer Attending and Certified under the Ontario Pesticide Education Program Grower Pesticide Safety Course. Evaluate Training Session Questionnaire Surveys administered to farmers by the University of Guelph (Ridgetown College) who have attended the Ontario Pesticide Education Program Grower Pesticide Safety Course. USDA tracks the amount of pesticides used by weight by farmers within the Great Lakes Basin to indicate reductions of use by farmers through pesticide user surveys as an indicator of the adoption of more sustainable agricultural practices.

*Background*
Research has found that reliance on pesticides in agriculture is overwhelming and that it would be impossible to abandon their use in the short term. Most consumers want to be able to purchase inexpensive yet wholesome food. Currently, other than organic production, there is no replacement system readily available at a reasonable price for consumers, and at a lesser cost to farmers that can be brought to market without pesticides.

*Purpose*
To assess the adoption and uptake of Integrated Pest Management practices by farmers and to infer environmentally friendly practices in place, to prevent ground and surface water contamination.

*Ecosystem Objective*
This indicator supports Article, V1 (e (I, viii) – Programs and other Measures (Pollution for Agriculture), Annexes 1,2, 3, 11,12 and 13 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 affect bio diversity, lead to protection of soil, water quality as well as the sustainable future of agriculture and rural development and better ecological integrity in the basin. To produce effective results this indicator relies on optimum combinations of chemical, biological and cultural methods (such as crop rotation, tillage, weeding techniques, intensive monitoring and insect mating disruption. The indicator identifies the degree to which agriculture is becoming more sustainable and has less potential to adversely impact the Great Lakes ecosystem.

*Illustration*
The number/acres of Integrated Pest Management plans being practiced on cropland in the basin compared to the acres needed. This could be an illustrated on a percentage or acre basis. The growth or decline of crop protection chemicals on a long term trend basis.

*Limitations*
USDA only records the IPM plan data on an annual basis currently. It is assumed that these plans, which are voluntary, will be continue to be carried out. A violation of farm chemical

use would be a violation of state and federal laws. USDA does track the amount of chemicals applied but with rapid chemical and technology changes it would be difficult to develop accurate trends.

*Interpretation*

Having complete records of IMP's developed and/or chemicals used would provide a better indication of operator's acceptance of environmentally sustainable practices. This data will serve as a baseline for future trends.

*Comments*

Chemicals, technology and legislation are continually changing so the indicator will need to be updated and revised as needed.

*Relevancies*

Indicator Type: human activity
Environmental Compartment(s): land
Related Issue(s): stewardship
SOLEC Grouping(s): land use
GLWQA Annex (es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

*Last Revised*

Aug 17, 2002

Integrated Pest Management (sample report)
New Indicator

## Purpose

A goal for agriculture is to become more sustainable through the adoption of more non-polluting, energy efficient technologies and best management practices for efficient and high quality food production. This indicator reports the adoption of Integrated Pest Management (IPM) practices and the effects IPM has toward preventing surface and groundwater contamination in the Great Lakes Basin. This indicator reports at least 2 basic things:

1. Measurement of the acres of agricultural pest management planned for field crops, to reduce adverse impacts on plant growth, crop production and environmental resources.

2. Reporting the results of a questionnaire/course evaluation administered to farmers in Ontario by the University of Guelph (Ridgetown College) / Ministry's of Environment and Energy who have attended the Ontario Pesticide Training and Education Program Grower Pesticide Safety Course.

## Ecosystem Objective

This indicator supports Article V1 (e (1,viii) Programs and other Measures (Pollution from Agriculture) Annex 1, 2, 3, 11, 12 and 13 of the GLWQA. The objective is the sound use and management of soil, water air, plants and animal resources to prevent degradation. Pest Management is controlling organisms that cause damage or annoyance. Integrated pest management is utilizing environmentally sensitive prevention, avoidance, monitoring and suppression strategies to manage weeds, insects, diseases, animals and other organisms (including invasive and non-invasive species) that directly or indirectly cause damage or annoyance. Environmental risks of pest management must be evaluated for all resource concerns identified in the conservation planning process, including the negative impacts of pesticides in ground and surface water on humans and non-target plants and animals. The pest management component of the conservation plan must be designed to minimize negative impacts of pest control on all identified resource concerns.

## State of the Ecosystem

Agriculture accounts for approximately 35% of the land area of the Great Lakes basin for example, and dominates the southern portion of the basin. Although field crops such as corn and soybeans comprise the most crop acreage, the basin also supports a wide diversity of specialty crops. The mild climate created by the Great Lakes allows production of a variety of vegetable and fruit crops. These include tomatoes (for both the fresh and canning markets), cucumbers, onions and pumpkins. Orchard crops such as cherries, peaches and apples are economically important commodities in the region, along with grape production for juice or wine. These agricultural commodities are major users of pesticides.

Research has found that reliance on pesticides in agriculture is significant and that it would be impossible to abandon their use in the short term. Most consumers want to be able to purchase inexpensive yet wholesome food. Currently, other than organic production, there is no replacement system readily available at a reasonable price for consumers, and at a lesser cost to farmers that can be brought to market without pesticides.

With continued application of pesticides in the Great Lakes basin, non-point source pollution of nearshore wetlands and the effects on fish and wildlife is a concern. Unlike point sources of contamination such as at the outlet of an effluent pipe, nonpoint sources are more difficult to define. An estimated 21 million kg of pesticides are used annually on agricultural crops in the Canadian and American Great Lakes Watershed (GAO 1993). Herbicides account for about 75% of this. These pesticides are frequently transported via sediment, ground or surface water flow from agricultural land into the aquatic ecosystem. With mounting concerns and evidence of the effects of certain pesticides on wildlife and human health it is crucial that we determine the occurrence and fate of agricultural pesticides in sediments, aquatic and terrestrial life found in the Great Lakes. Atrazine and metolachlor were measured in precipitation at nine sites in the Canadian Great Lakes Basin in 1995. Both were detected regularly at all nine sites. The detection of some pesticides at sites where they were not used provides evidence of atmospheric transport of pesticides in this region.

Cultural controls (such as crop rotation and sanitation of infested crop residues), biological controls, and plant selection and breeding for resistant crop cultivars have always been an integral part of agricultural IPM. Such practices were very important and widely used prior to the advent of synthetic organic pesticides; indeed, many of these practices are still used today as components of pest management programs. However, the great success of modern pesticides has resulted in their use as the dominant pest control practice for the past several decades, especially since the 1950s. Newer pesticides are generally more water soluble, less strongly adsorbed to particulate matter, and less persistent in both the terrestrial and aquatic environments than the older contaminants but have still been found in precipitation at many sites.

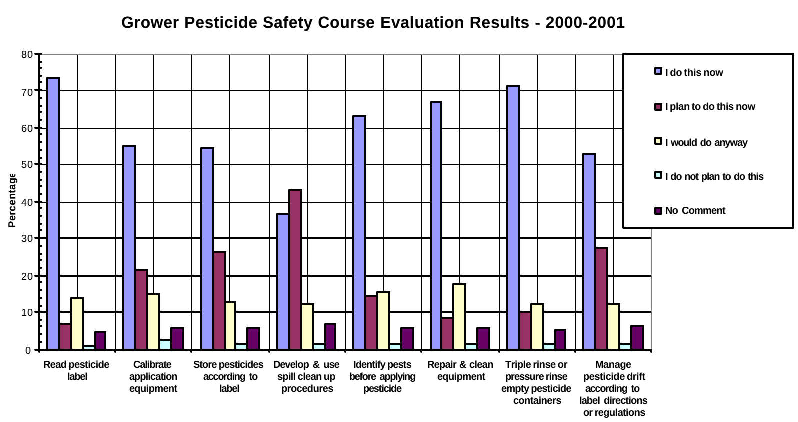


Figure 1. Grower Pesticide Safety Course Evaluation Results 2000-01
(Source: Ontario Ministry of Agriculture & Food and the University of Guelph)

The Ontario Pesticides Education Program provides farmers with training and certification through a pesticide safety course (Fig. 1). The USDA Natural Resources Conservation Service reported that pest management practices were planned for 201,042 acres of cropland in the US Great Lakes Basin for Fiscal Year 2001 (Fig.2).

Future Pressures

Pest management practices may be compromised by changing land use and development pressures (including higher taxes); flooding or seasonal drought; and lack of long-term financial incentives for adoption of environmentally friendly practices. In order for pest management to be successful, pest managers must shift from practices focusing on purchased inputs and broad-spectrum pesticides to those using knowledge about ecological processes. Future pest management will be more knowledge intensive and focus on more than the use of pesticides. The public sector, university Cooperative Extension programs and partnerships with grower organizations are an important source for pest management information, and dissemination, especially considering that the public sector is more likely to do the underlying research. However, there is significant need for private independent pest management consultants to provide technical assistance to the farmer.

Future Actions

All phases of agricultural pest management, from research to field implementation, are evolving from its current product-based orientation to one that is based on ecological principles and processes. Such pest management practices will rely more on an understanding of the biological interactions that occur within every crop environment, and the knowledge of how to manage the cropping systems to the detriment of pests. The optimum results would include fewer purchased inputs (and therefore a more sustainable agriculture), as well as fewer of the human and environmental hazards posed by the broad spectrum pesticides so widely used today.  Although pesticides will continue to be a component of pest management, the following are significant obstacles to the continued use of broad- spectrum pesticides: pest resistance to pesticides; fewer new pesticides; pesticide-induced pest problems; lack of effective pesticides; and human and environmental health concerns.

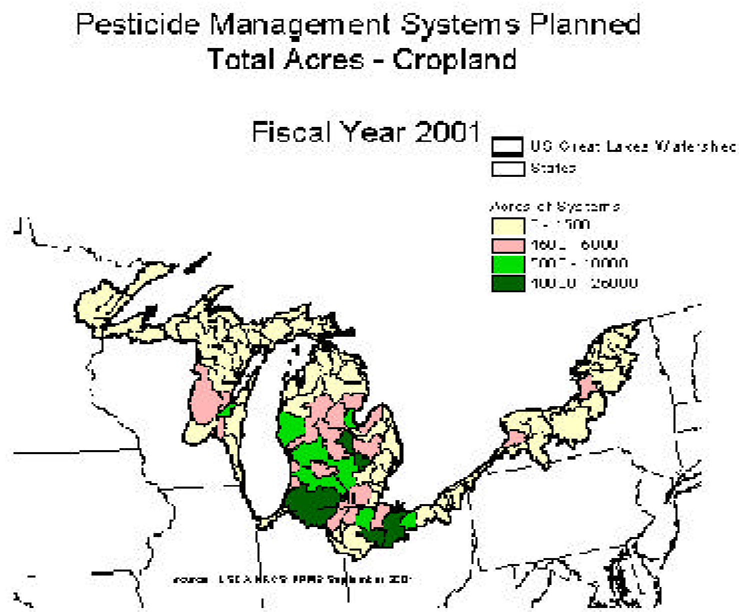


Figure 2. Annual U.S. Pesticide Management Systems Planned for FY 2001.
(Source: USDA, NRCS, Performance and Results Measurement System)

Based upon these issues facing pesticide use, it is necessary to start planning now in order to be less reliant on broad-spectrum pesticides in the future. Society is requiring that agriculture become more environmentally responsible through such things as the adoption of Integrated Pest Management.  This will require effective evaluations of existing policies and implementing programs for areas such as Integrated Pest Management.  To reflect these demands there is a need to further develop this indicator.  These types of future activities could assist with this process.

- Indicate and track future adoption trends of IPM best management practices
- Further evaluate the success of the Ontario Pesticide Training Course by such as adding survey questions regarding IPM principles/practices to course evaluation materials.
- Evaluate the number of farmers/vendors certified, attending and failing the Ontario Pest Education Program.
- Analyze rural water quality data for levels of pesticide residues.

Note: Grower pesticide certification is mandatory by Ontario law and applies to individual farms as well as custom applicators.

Acknowledgments

Authors: Ruth Shaffer and Roger Nanney, USDA-Natural Resources Conservation Service, and Peter Roberts and Jean Rudichuk, Resources Management, OMAF, Guelph, Ontario.

# 6. Forestry Indicators

Since 1998 it has been recognized that the suite of Great Lakes indicators was lacking in a vital inland component of the ecosystem - forestry. The following list of 12 proposed indicators look at the state of forestry in the Great Lakes basin, pressures on forestry, the impacts of forestry on water quality and some of the human activities to mitigate the pressures on the forestry component.

Listing of proposed forestry indicators:

1. Area of Forest Cover Types - looks at the proportion of forest area in each cover type and age-class (or successional stage).
2. Forest Species at Risk - looks at the abundance of and trends in rare, threatened and endangered forest-based species.
3. Featured Species - looks at the amount of habitat for selected forest species.
4. Forest Land Base - looks at trends in the area of forest land due to land use change, including, deforestation and afforestation.
5. Forest Fragmentation - looks at fragmentation of forest types.
6. Best Management Practices for Water Quality - looks at compliance with and effective ness of water quality Best Management Practices.
7. Non-native Forest Species - looks at the area and severity of occurrence of non-native (invasive species) species detrimental to forest condition.
8. Forest land ownership and utilization. (to be defined)
9. Forest Useage - looks at ranges of uses of the forest and meanings for those uses.
10. Forest based employment picture by sector.
11. Public Participation in Forestry Decisions - looks at the representativeness of all publics in the public participation process.
12. Sustainable Forest Management - looks at the capacity to measure and monitor changes in the conservation and sustainable management of forests.

In the following section there is a description for each indicator to help generate discussion about how appropriate and useful each indicator is and also to allow participants to screen the indicators against the criteria of necessary, sufficient and feasible.

Other forestry indicators proposed for future consideration (but descriptors have not been included at this time):

13. Area and percent of forest affected by damaging agents - possibly including forest fire acreage/hectares.
14. Recreational use of forests.
15. Wood product shipments/imports - perhaps related to Great Lakes shipping.
16 The rate of consumption as compared to wood products production as compared to imports.

Area of Forest Cover Types
New Indicator

*Measure*
Proportion of forest area in each forest cover type and age class (or successional stage)

*Purpose*
The area of each forest cover type based on dominant tree species and supplementary information related to canopy cover, height and age, provide the best spatial surrogate of forest habitat available with current forest inventory data bases in the Great Lakes basin. While trees in themselves do not constitute the sole source of biodiversity in a forest ecosystem, at a coarse level of resolution, they do have a strong influence on understory composition, structure and successional development that in turn influences the survival of forest dependent animals. In general this indicator provides a benchmark of how much component forest habitats in the landscape have deviated through time and to what extent biodiversity at the ecosystem, species and genetic level may be placed at risk relative to background historical conditions.

*Ecosystem Objective*
The maintenance of existing forest biodiversity in the Great Lakes basin.

*Endpoint*
To identify where trends in the proportion of forest cover types represent a risk to constituent biodiversity and develop remedial actions to reverse the trend.

*Features*
Issues of forest biodiversity are very complex because forest ecosystems by their nature are dynamic, responding to spatial variation in climate and soil moisture and nutrient regimes and temporal variation due to varying rates of natural senescence or different types or frequencies of disturbances. Where there is a relative consensus on the historical extent of forest types and their natural successional trends, comparison of historical and extant conditions may provide a relative measure of how successful current management is emulating natural trends and thereby protecting biodiversity.

*Illustration*
Data is tabulated by forest cover types by species and age classes as a proportion of total forest area. Individual graphs can be constructed for each cover type to show trends through time.

*Limitations*
This approach is problematic in areas where there have been extensive conversions of forests to other cover types such as agricultural or urban landscapes. Although the data is expensive to collect most jurisdictions in the Great Lake basin routinely collect this data in support of forest management planning.

*Interpretations*
Where the proportion of forest cover types is near that of historical conditions and the age class distribution suggests a sustainable trend, we can assume that biodiversity should not be impacted by habitat loss due to management decisions. Where particular cover types form a small proportion of the total forest or the age classes suggest gaps in successional stages, this would indicate potential risks to biodiversity objectives.

*Comments*

This indicator is based on proportion of total forest area but needs to be used in conjunction with other indicators that take into account other factors such as absolute area and fragmentation. This indicator is equivalent to the Great Lakes Forest Alliance indicators #1 & #2 and Montreal Process indicators 3.1 a & b.

*Unfinished Business*

Indicator has to be vetted through the SOLEC evaluation criteria.

*Relevancies*

Indicator Type: state
Environmental Compartment(s): land
Related Issues: habitat
SOLEC Groupings: land use
GLWQA Annex(es):
IJC Desired Outcome(es): 6. Biological Community Integrity and Diversity
Beneficial Use Impairment(s): Loss of Forest Habitat

*Last Revised*

August 15, 2002

Forest Species at Risk
New Indicator

*Measure*
Abundance of rare, threatened and endangered forest-based species.

*Purpose*
To determine if trends in populations of forest dependent species at risk in the Great Lakes basin are improving or getting worse.

*Ecosystem Objective*
To maintain the species diversity of Forest Ecosystems in the Great Lakes basin.

*Endpoint*
Population trends for rare, threatened and endangered forest dependent species are not decreasing through time.

*Features*
This indicator is a simple measure of the population dynamics expressed as density or frequency at selected time steps of 1-5 years depending on the species and availability of data. This indicator can be used in conjunction with other proposed forest indicators (see indicators 1, 3, 4, & 5 listed in section 6) to interpret possible causes for observed trends.

*Illustration*
This indicator will be plotted as the change in density and / or frequency of selected rare, threatened and endangered forest species through time.

*Limitations*
The terms rare, threatened and endangered are well defined and lists are well established in U.S. and Canada. However, the type and extent of forest habitats needed to maintain populations is not always well established and it is sometimes difficult to separate habitat availability from other factors, such as hunting, as causal agents in the species demise.

*Interpretation*
Generally, further declines in the populations of rare, threatened and endangered species has to be interpreted as a negative trend. However, establishing the cause for negative trends depends on intimate knowledge on a case by case basis of population interactions with habitat quality opposed other factors such as predator interactions, disease, pollution etc.

*Comments*
In the comparison of trend over time data, particularly for rare species, it is critical that consistent methodology be applied to ensure that trends are real and not artifacts of sampling. This indicator is equivalent to the Great Lakes Forest Alliance indicator #3 and Montreal Process indicator 3.1.2b.

*Unfinished Business*
The indicator still has to be vetted through the SOLEC evaluation criteria.

*Relevancies*
Indicator Type:
Environmental Component(s):

Related Issues:
SOLEC Grouping(s):
IJC Desired Outcome (s):
GLFC Objective(s):
Beneficial Use Impairment(s):

*Last Revised*
August 15, 2002

Featured Species
New Indicator

*Measure*
Abundance of selected forest-based species.

*Purpose*
This indicator will be used to assess the abundance of featured species other than rare, threatened and endangered species to provide some synoptic measure of biological integrity.

*Ecosystem Objective*
To maintain populations of species considered to be indicators of biological integrity.

*Endpoint*
Forest ecosystems showing declining trends in populations of selected indicator species will be considered to have reduced biological integrity.

*Features*
This indicator will overlap with the Biological Integrity indicators. Ideally there needs to be some consensus on species that occur throughout forests of the Great Lakes basin whose populations are monitored using consistent methodology on a 1-5 year time frame. Game species generally have good statistics but these are not necessarily the best indicators since fluctuations are due to complex relationship between hunting success and ecosystem condition.

*Illustration*
Population estimates for selected forest indicator species expressed as density or frequency over time.

*Limitations*
This indicator is problematic with respect to the selection of appropriate species and establishing the linkage between population trends of the species and integrity of the forest ecosystem. Ideally, the indicator species should be basin wide, from similar habitats and selected by expert consensus based on sensitivity to changes forest habitat condition.

*Interpretation*
The interpretation will be increasing complex the more variables are introduced (i.e. sampling, habitat, prey-predator relations, hunting etc). A few good indicator species with consistent occurrence across similar habitats in the Great Lakes basin will provide better quality of interpretation.

*Comments*
The selection of indicator species is subjective but technically complex requiring the development of expert consensus. This indicator is equivalent to the Great Lakes Forest Alliance indicator #5.

*Unfinished Business*
The selection of forest indicator species that can be synoptic of forest ecosystem integrity.

*Relevancies*
Indicator Type: state

Environmental Compartment(s): land
Related Issues: habitat
SOLEC Groupings: land use
GLWQA Annex(es):
IJC Desired Outcome(es): 6. Biological Community Integrity and Diversity
Beneficial Use Impairment(s): Loss of Forest Habitat

*Last Revised*
August 15, 2002

Forest Land Base
New Indicator

*Measure*
Trends in the total area of forest land base.

*Purpose*
This indicator is intended to track trends in the expansion or contraction of land covered by forests or successional stages of forest through time.

*Ecosystem Objective*
To maintain forests as a critical component of the Great Lakes basin ecosystem.

*Endpoint*
The current total area covered by forests should be maintained or increased to compensate for widespread historical losses.

*Features*
This indicator is closely linked to other land use indicators since in a fixed area of land, increases in land use for one purpose usually lead to losses for another. In the application of this indicator relative success or failure in meeting ecosystem objectives can be judged by comparison to a long-term retrospective estimate of the historical cover of forests. In some parts of the basin historical losses may never be recovered and maintenance of extant forest cover may be a more realistic measure of success.

*Illustration*
Trend in total area of forest cover (including successional stages) by decade. Ideally, it should be possible to illustrate trends through at least 3 decades using satellite images but extant values as a baseline are readily available.

*Limitations*
This indicator could be costly, however there are very few technological limitations in providing estimates provided a standard definition of "forest" can be established across political jurisdictions. The separation of young successional stages that are adequately stocked from those where regeneration has failed will be problematic at a coarse level of resolution.

*Interpretation*
Generally the maintenance of extant proportions of forest cover through time should be judged as some measure of success. The assumption would be that deforestation losses in some areas due to agricultural expansion, urbanization etc. can be compensated by equal gains in afforestation in other areas.

*Comments*
Estimates of extant forest cover have already been developed by the Great Lakes Forest Alliance for jurisdictions in the Great Lakes basin with the exception of New York state. These estimates would need to be revised to exclude areas outside the basin. This indicator is equivalent to the Great Lakes Forest Alliance indicators #3 & #8.

*Relevancies*
Indicator Type:
Environmental Component(s):

Related Issues:
SOLEC Grouping(s):
IJC Desired Outcome (s):
GLFC Objective(s):
Beneficial Use Impairment(s):

*Unfinished Business*
The indicator must be evaluated using SOLEC criteria.

*Last Revised*
August 15, 2002

## Forest Fragmentation
New Indicator

*Measure*
Proportion of forest landscape in mean patch size classes.

*Purpose*
The fragmentation of forests can disrupt important ecological processes and habitat structure for certain forest dependent species. A measure of fragmentation is needed to ensure that components of forest biodiversity are not negatively impacted.

*Ecosystem Objective*
To maintain genetic, species and forest ecosystem diversity in the Great Lakes basin.

*Endpoint*
Generally, fragmentation would be considered to be an increasing problem as the proportion of large patches (100+ hectares) of mature and old growth successional stages decreased.

*Features*
Indicators of forest fragmentation are identified by the Great Lakes Forest Alliance, the Montreal Process and CCMD criteria and indicator frame works for sustainable forest management. The Ontario Ministry of Natural Resources 2002 State of the Forest Report provides an example of 5 patch size classes applied to the province of Ontario (Fig 1.1.4a).

*Illustration*
The indicator could be presented as a simple histogram of patch size class as a proportion of total forest area or spatially as a map showing the distribution patch size classes throughout the Great Lakes basin.

*Limitations*
This indicator would be resource demanding requiring a specialized analysis of satellite imagery using spatial statistics.

*Interpretation*
The interpretation of this indicator is very complex, especially where the differences in proportion of patch sizes is not pronounced. Different forest species require different successional stages, many use several stages on a daily or annual basis. Generally “forest interior” are the most highly impacted by fragmentation. Also, not all fragmentation is a result of human activities, some landscapes are natural mosaics of different habitats to which the local flora and fauna are fully adapted.

*Comments*
The basin wide application of this indicator would require the development of consensus on critical patch size classes and appropriate protocols for analysis by participating jurisdictions. This indicator is equivalent to the Great Lakes Forest Alliance indicator #9 and Montreal Process indicator 3.1.1e.

*Unfinished Business*
The indicator needs to be screened using SOLEC evaluation criteria.

*Relevancies*
Indicator Type:
Environmental Component(s):
Related Issues:
SOLEC Grouping(s):
IJC Desired Outcome (s):
GLFC Objective(s):
Beneficial Use Impairment(s):

*Last Revised*
August 15, 2002

Best Management Practices for Water Quality
New Indicator

*Measure*
Compliance with Best Management Practices guidelines for the protection of water quality.

*Purpose*
To ensure water quality of forest tributaries in the Great Lakes basin is not compromised by forestry practices.

*Ecosystem Objective*
To maintain water quality and aquatic habitats in forest tributaries entering the Great Lakes.

*Endpoint*
Full compliance with Best Management Practices guidelines for water quality throughout the Great Lakes basin.

*Features*
Government and industrial agencies responsible for forest management in jurisdictions throughout the Great Lakes basin have developed guidelines to mitigate impacts of forest practices on water quality and aquatic habitats. These guidelines generally require the maintenance of riparian forest buffers around water bodies and strict specifications for road stream crossings.

*Illustration*
Compliance can be expressed as the percent of observations free of infractions over total observations.

*Limitations*
The measure is only reliable if there is some level of consistency in the frequency and intensity of inspections among jurisdictions. However, cost should not be a significant factor since most jurisdictions are already undertaking some level of compliance inspections.

*Interpretation*
Since there is some level of variation in the number, type and terminology surrounding Best Management Practices guidelines across jurisdiction, there is a need to find some common denominators for cross-basin reporting.

*Comments*
The computation and interpretation of compliance is relatively straight forward if consensus can be developed on specific guidelines and terminology to use. This indicator is equivalent to the Great Lakes Forest Alliance indicator #10.

*Unfinished Business*
Evaluation of the indicator using SOLEC criteria.

*Relevancies*
Indicator Type:
Environmental Component(s):
Related Issues:
SOLEC Grouping(s):

IJC Desired Outcome (s):
GLFC Objective(s):
Beneficial Use Impairment(s):

*Last Revised*
August 15, 2002

Non-native Forest Species
New Indicator

*Measure*
Area and severity of occurrence of invasive species detrimental to forest condition.

*Purpose*
To ensure adequate forest health monitoring is done in the Great Lakes basin for the timely detection and control of invasive species detrimental natural forest ecosystems.

*Ecosystem Objective*
To protect the biological integrity of forests in the Great Lakes basin from invasive species.

*Endpoint*
The maintenance of detrimental invasive species populations in the basin forests at zero.

*Features*
Threats of invasive species to forest biological integrity are well documented in cases such as White Pine Blister Rust, Chestnut Blight and Dutch Elm Disease that have devastated populations of native tree species. Although surveillance has generally increased due to historical attacks , increased globalization in trade has increased the risk of introductions. This indicator has a lot in common with the proposed non-native species indicator (#9002) in terms of vectors.

*Illustration*
The indicator should be expressed graphically as trend over time area of forest impacted by detrimental invasive species.

*Limitations*
The indicator may be limited by variations in the intensity and frequency of forest health surveillance.

*Interpretation*
The separation of invasive species that are “detrimental” from “not detrimental” requires some expert assessment of the relative threat of invasive species to the biological integrity of forests.

*Comments*
The frequency and intensity of surveillance should be provided as background information for the interpretation. This indicator is equivalent to the Montreal Process indicator #3.3a.

*Unfinished Business*
Evalauation of the indicator using SOLEC criteria.

*Relevancies*
Indicator Type:
Environmental Component(s):
Related Issues:
SOLEC Grouping(s):
IJC Desired Outcome (s):
GLFC Objective(s):

Beneficial Use Impairment(s):

*Last Revised*
August 15,2002

Forest Useage
New Indicator

*Measure*
Change in uses over time; acceptability of those changes in relation to fishing, hunting, wildlife watching, snowmobile licenses, snowmobile trails, off-road vehicle licenses and trails, hiking pathways, cross-country ski trails, in-line skating trails, horseback riding trails, campgrounds and campsites, outfitters and rental rates.

*Purpose*
People use forests in many ways including consumptive activities like timber harvest, hunting and gathering as well as a wide range of non-consumptive recreation activities. These activities often have meanings for people above and beyond participation in the activity itself. For example, gathering and exchange of forest products such as berries or mushrooms can be very important to people not only for economic and recreational reasons but also because the activity maintains both social ties in the community and community values (e.g. self-sufficiency and independence). The identification of the complete range of uses is not always easy or obvious. Sustainable forest management maintains the range of uses that are important locally as well as regionally.

*Ecosystem Objective*
The more people are involved in forest-related activities, from bird watching to timber harvesting, the greater will be their investment to monitor, conserve and sustain the forested land of the Great Lakes watershed. Carrying capacity will need to be targeted for each recreational activity.

*Endpoint*
The range and frequency of people who directly interact with the forest resource will be stable or increasing though not exceed the identified carrying capacity.

*Features*
This indicator has data of value to and can be measured at state/provincial, county/forest management unit, community and woodlot scales.

*Illustration*
The trends in usage will be charted collectively to illustrate an increase or decrease in various recreational, gathering, forest non-timber products as well as timber harvesting as an overlay.

*Limitations*
The data collection will be relatively costly but can utilize the existing resource capacities of groups such as Extension Services in the United States or tourism departments who county-by-county could collect quantitative data. Quantitative data could also be collected through special project efforts if the commitment of people to the forest resource is a desirable measure.

*Interpretation*
If the number of individuals engaged in forest-related activities drops, if the range of one kind of recreational activity increases as another decreases, or if the number of user days spiked, the trends might all signal the need for further market studies or educational efforts.

*Comments*

Many Extension Service and tourism bureaus are collecting post-visitor experiences and could add these data sets to their collections. This indicator is equivalent to the Great Lakes Forest Alliance indicator #25 and Montreal Process indicator 6.0.

*Unfinished Business*

Forest-based visitor days research are complex. Licensed recreational use can give trend information but are ineffective to define the level of silent, passive or unlicensed sports. Further complexity is the conversion of visitor days vs. recreational use by local residents. While some communities have conversion studies, research is needed as well as partnership with tourism agencies to identify an index of the recreational days to aggregate to the watershed level.

*Relevancies*

Indicator Type:
Environmental Compartment(s):
Related Issue(s):
SOLEC Grouping(s):

*Last Revised*

August 8, 2002

Public Participation in Forestry Decisions
New Indicator

*Measure*
The levels at which people attend, participate, volunteer and help make decisions. Numbers of people participating are representative of the relevant level of analysis (community, state/ province, region). The types of people participating are representative of the relevant level of analysis (community, state, region). Ratings of fairness principles by people who have participated and ratings of perceived fairness by people who have not participated - both can be gathered through careful surveys of people who participate in public processes.

*Purpose*
Citizen support for sustainable forest management will occur if citizens have meaningful opportunities to participate in decisions about the forests. Citizens will enhance the quality of forest management activities using their indigenous knowledge, historical perspective and value diversity. There is widespread agreement in the literature that citizen support for sustainable forestry will only occur if citizens have meaningful opportunities to participate in decisions about the forest resource. In addition, all citizens are dependent on forest resources in multiple ways. Therefore, an indicator of sustainable forest management is whether all publics are included in the process. Sustainable forest management will not occur if people do not participate and people will not participate if they perceive that the processes are not fair and just. Therefore, an indicator of sustainable forest management is whether public participation processes in SFM are perceived as fair and just (voice, broad representation, lack of bias, accurate information, control over processes and outcomes, respect, listening, trust).

*Ecosystem Objective*
An increasing number and diversity of people will be involved in an increasing level of involvement in the forest resource management and will perceive decisions are just.

*Endpoint*
The forest resource of the watershed will be managed to sustain the forested regions of the watershed and provide the ecological benefits.

*Features*
This indicator can be monitored at the county or forest management unit, state or provincial and/or national forest levels. Tools to educate the public in non-biased manner of the complexities of sustainable forest management must be developed and used to ensure citizens can participate meaningfully.

*Illustration*
Quantitative data will be graphed depicting the numbers and types of people involved in forest management planning. A spiral, indicating depth of participation will be used to show the depth of their levels of participation (from an open house, participation in woodland owner or Model Forest programmes, to volunteering in a monitoring project or forest management activity such as loosestrife eradication and decision-making processes).

*Limitations*
The data collection will be relatively costly but efforts from other organizations, such as the Communities Committee and the Model Forest Programme can be utilized to maximize data collection efforts.

*Interpretation*
The enhanced diversity of an increasing number of people involved in increasingly complex opportunities should be evident. Decreases in any of those three areas should signal concern and a need to adjust forest management planning decision-making and educational outreach efforts.

*Comments*
The region has the social science research capacity at university and research stations as well as in forest community research facilities. This indicator is equivalent to the Great Lakes Forest Alliance indicator #32 and Montreal Process indicator 4.1c.

*Unfinished Business*
A protocol for data collection must be developed and accepted across forest management ownerships.

*Relevancies*
Indicator Type:
Environmental Compartment(s):
Related Issue(s):
SOLEC Grouping(s):

*Last Revised*
August 8, 2002

Sustainable Forest Management
New Indicator

*Measure*
Some potential measures include: number and diversity of available incentives; profitability incentives; tax incentives; conservation easements; technical assistance; landowner education opportunities; tax deferral programs; private forest legislation; land use planning legislation and policy; existence of plans for forest lands; integration of plans (e.g. across region using FIA process); quality of data; and monitoring and auditing activities.

*Purpose*
In order to have sustainable forest management, it is necessary to have laws and policies in place that facilitate rather than constrain these activities and practices which help citizens participate in the monitoring processes. The existence of laws, policies, practices and regulations is an indicator of whether sustainable forest management is possible. This indicator also includes policies and regulations that facilitate planning for forest lands. In order to have sustainable forest management, there need to be incentives. The availability of such incentives is therefore an indicator of whether sustainable forest management is possible. Incentives can be public or private.

*Ecosystem Objective*
An increasing number of people will be involved in an increasing level of participation in measuring and monitoring changes in the conservation and management of forests in the watershed. An array of incentives exist to encourage forest lands to remain forested.

*Endpoint*
Participatory research will exist throughout the watershed for monitoring the SOLEC indicators. People will urge response to threatening conditions and celebrate enhancements. Forested lands will remain forested.

*Features*
Participation in open and transparent processes for indicator monitoring, regardless of the measurement scheme, can be tracked. Natural resource agency Best Management Practices, certification schemes, local community forestry groups, model forest programmes, industry certification and third party monitoring systems can be tracked.

*Illustration*
A map of the Great Lakes watershed can be developed with a key to indicate the array of monitoring systems and their geographic location, color coded by scheme.

*Limitations*
It is possible that not all geographic areas will be covered but should expand continuously. Participatory research has validity and reliability and needs recognition by the scientific community but is not always respected at this time.

*Interpretation*
Gaps in geographic areas or a limit to the diversity of monitoring schemes might signal a need for greater public outreach. A limit in the diversity of ages, ethnicity, gender may also signal concern and a need for education.

*Comments*
Natural resource agencies, certification schemes and community groups can be involved in the monitoring processes. This indicator is equivalent to the Great Lakes Forest Alliance indicator #32 and Montreal Process indicator 7.3.

*Unfinished Business*
Conceptual aggregation of the data is possible and protocol should be developed to make this qualitative data meaningful. Development of community forestry groups, such as the Model Forest Programme will enhance the replicability of the monitoring efforts.

*Relevancies*
Indicator Type:
Environmental Compartment(s):
Related Issue(s):
SOLEC Grouping(s)

*Last Revised*
August 8, 2002

# 7. Groundwater Indicators

## 7a. Description of Groundwater the Indicators Project

The inclusion of indicators of groundwater quality and quantity in the SOLEC process arose out of the need for action on Annex 16 of the Great Lakes Water Quality Agreement (GLWQA). Since the signing of the Agreement there has been a lack of work involving the study of groundwater. The IJC's10th Biennial Report on Great Lakes Water Quality suggested that an indicator for stream base flow would serve as an evaluation of groundwater supply, as well as meet the requirements of Annex 16: Pollution from Contaminated Groundwater. Following these recommendations by the Indicators Implementation Task Force (IITF), the SOLEC Steering Committee initiated a groundwater workgroup to develop the groundwater indicators.

Indicators to groundwater quality and quantity were suggested over the course of several meetings with members from Environment Canada, the International Joint Commission, U.S. Geological Survey, and the Ontario Ministries of Natural Resources and the Environment. Discussions proceeded to determine which indicators could currently provide usable information based on available data, and those, which could be initiated and data collection begun quickly and easily.

With the purpose of evaluating the effectiveness of the suggested groundwater indicators, a set of six sample watersheds was nominated. Current data and monitoring programs will be considered, to determine if there is a sufficient amount of information available at present, and if the data available will support the use of the indicators that are proposed. Summaries of this process will be presented at SOLEC 2002.

### Scope

Living in the Great Lakes basin has given us an "abundance mentality" regarding water supply, however the fact is that both pumping and contamination are stressing many of our aquifers. Groundwater levels have declined over large areas, such as the aquifers outside Chicago, Illinois, near Toledo, Ohio and near Milwaukee and Fox River-Green Bay, Wisconsin (Grannemann et al, 2000). Groundwater withdrawal in 1995 for the Great Lakes region was estimated to be 1,510 Mgal/day (million gallons per day) (Solely et al, 1998). With populations growing at exponential levels, this rate of withdrawal may soon deplete our groundwater supplies past rechargeable levels.

Contamination of groundwater also continues, as more and more people become reliant on the source. New wells are bored each year, sometimes in areas that are extremely vulnerable to contamination. Our demand for better quality crops has increased our withdrawals for irrigation water, and at the same time increased the chances of contaminating our aquifers with agricultural chemicals. Leaking underground storage tanks and road salting also contribute to the brew mixing in our groundwater supply. Prevention from contamination and the protection of our groundwater sources is necessary, as groundwater, once contaminated, will rarely be fit for human consumption again.

### THE IMPORTANCE OF GROUNDWATER TO SOLEC

#### An Essential Component of the Hydrologic Cycle

Groundwater is an important component of the cycling of water on our planet. Water released as precipitation from the atmosphere infiltrates through the soil where it can be taken up by plants or continues to soak into the ground, and becomes part of the groundwater. During this process the soil acts as a filter, removing bacteria, sediment and other insoluble forms of contamination that become trapped within the soil pores. Some chemicals become adsorbed (attached) to the soil particles, thereby preventing or slowing the movement of these pollutants into the groundwater, while other, more soluble pollutants remain in the water.

Groundwater also discharges into lakes, streams and wetlands, replenishing or maintaining water levels. Where the water table reaches the bottom of a surface water body, groundwater may seep or flow into the surface water, recharging the supply. Estimates have suggested that groundwater contributes approximately 48 percent to the stream flow of tributaries of Lake Erie, and 79 percent to the tributaries of Lake Michigan (Holtschlag and Nicholas 1998). In headwater streams, groundwater is often the largest source of recharge. During late summer months, when precipitation is low and evaporation high, groundwater may contribute up to 100 percent of the stream flow, forming the majority of the base flow. Thus, the quality of groundwater and surface water is closely related, and efforts to protect one or the other require efforts to protect both.

### Provides Habitat for Aquatic Life

The discharge of groundwater to wetlands, lakes and rivers is an essential component of habitat, and is necessary for the reproduction and survival of many animals. Some wetlands, like those on higher ground, serve as essential groundwater recharge areas, while others may receive the majority of their waters from groundwater discharge. Consequently, a change in volume or quality of the groundwater entering these wetlands may have detrimental effects on the wildlife population. Brook trout spawn in the fall in shallow areas where there is cold, clear spring water upwelling through gravel (Hedley’s Trout Farm, 2002). The presence of watercress often indicates suitable habitat for brook trout. Cedar trees and some aquatic insects are also found only in streams with large groundwater contributions (Hedley’s Trout Farm, 2002). Furthermore, groundwater discharge often affects the temperatures of the stream, stabilizing the temperatures and thus lessening the stress on the aquatic life.

### Threats to Groundwater Quality: Contamination

Groundwater in selected areas of the Great Lakes is vulnerable to broad-scale contamination by nitrates, chloride, pesticides, and volatile organic compounds from land-use activities such as agriculture and urban development (Thomas, 2000b; Saad, 1996, 1997). The closer the water table or aquifer is to the surface of the land; the greater is the vulnerability of this resource to contamination. Wells in rural areas are most often contaminated with fertilizers and pesticides leaching off cropland, especially where irrigation is practiced (NAWQA). Owners of new homes built on old farmland may be exposing themselves unknowingly to a mixture of chemicals if they rely on groundwater for drinking water.

Seepage from sewage tanks and underground storage tanks for petroleum products have also been found to contaminate groundwater in the Great Lakes region. Industrial spills and improperly constructed and maintained landfills can contaminate groundwater in urban areas. Locations such as the infamous Hyde Park, Love Canal, and 102$^{nd}$ Street landfills located within miles of the Niagara River have contributed not only in the contamination of the river and groundwater, but also the contamination of Lake Ontario.

### Threats to Groundwater Quantity: Overdraw

As populations continue to expand, the need for clean drinking water often overrides the concern for a healthy water ecosystem. Thus, aquifers become stressed with the increase in withdrawals. This can lead to a lowering of the water table, and consequently, shallow wells become susceptible to drought and may run dry. Residential wells that tap the same aquifers as irrigation wells may also be affected by substantial declines in water level due to the effect of the cone of depression (Hoard and Westjohn, 2001). Currently, residents of Monroe County, Michigan are experiencing dry wells resulting from large groundwater withdrawals by local quarries. In some cases new wells have been drilled more than 200 feet down, without encountering water (Shine, 2002).

### The Impact on Human and Ecosystem Health

The contamination of our groundwater may leave us with water that is unfit and sometimes dangerous to drink. Levels of contaminants can sometimes exceed the health advisories set to protect human health. Nitrate concentrations over 10 mg/l have caused blue baby syndrome in infants, restricting their ability to breathe and sometimes causing death. The effects of contaminants such as pesticides and other chemicals may not be known explicitly, however, there is evidence of damage resulting from higher concentrations. Even low concentrations, which still exceed aquatic life advisory levels, can have effects. Fish and aquatic life in headwater streams may suffer reproductive or neurological effects, or sometimes mortality. The consumption of these effected fish may even affect our own health.

Large groundwater withdrawals may cause a decline in the natural groundwater discharge from springs. This discharge is crucial to maintaining stream flow and wetland hydrology, and to sustaining the quality and quantity of both aquatic and terrestrial ecosystem integrity and health. Without the input of groundwater, many streams will see an increase in temperature, which may have detrimental impacts on species such as brook trout and sculpin, that require cool waters for survival. At worst, groundwater fed streams may dry up during periods of low precipitation, killing whole communities that are dependant on groundwater discharge.

There are 7 proposed groundwater indicators. They are listed here with a brief description. A full description of each can be found in the following section with sample reports for three indicators: Base Flow due to Groundwater Discharge; Water Use and Intensity; and Natural Groundwater Quality and Human-Induced Changes.

### STATE INDICATORS

#### Base Flow due to Groundwater Discharge

This indicator will establish the percentage of stream flow that originates as groundwater, and will be used to determine areas that are important and sensitive groundwater-fed ecosystems.

#### Groundwater Dependant Plant and Animal Communities

This indicator will assess the status of plant and animal communities dependant on groundwater discharge into headwater streams, and it will be used to determine if the quality and quantity of groundwater discharge is sufficient to maintain a balanced ecosystem.

#### Groundwater and Amphibian Communities

This indicator will indicate the presence or absence of a set of groundwater dependant amphibian species, and will be used to determine the locations of groundwater-fed habitats.

PRESSURE INDICATORS

Water Use and Intensity

This indicator will show both percentage of wells used for each sector of the population and the intensity of the water use by that sector. It will also illustrate changes in supply and demand, through the records for new wells and those that have been deepened. The indicator will be used to infer the potential impacts of these water uses on the quality and quantity of groundwater.

Land Use and Intensity

This indicator will illustrate land use designation and the intensity of that land use, to infer the potential impacts on groundwater quality and quantity.

Natural Groundwater Quality and Human-Induced Changes

This indicator will assess groundwater quality based on the natural quality as determined by aquifer material and local features, and through water quality changes due to human activity. It will be used to determine quality of water for consumption and ecosystem functions, and to decide where protection programs should be employed.

RESPONSE INDICATORS

Managing the Groundwater Resource

This indicator will illustrate the progress made in groundwater management and protection and will be used to identify areas that are in need of further study and/ or protection.

## 7b. Proposed Groundwater Indicator Descriptions

This section includes a full description of each of the seven proposed Groundwater indicators. In addition there are sample reports for three of the indicators: Base Flow due to Groundwater Discharge; Water Use and Intensity; and Natural Groundwater Quality and Human-Induced Changes.

### Base Flow Due to Groundwater Discharge (description)

New Indicator

*Measure*

Base flow as a percent of stream flow (base flow index).

*Purpose*

This indicator measures the contribution of base flow due to groundwater discharge to total stream flow by sub-watershed and is used to detect the impacts of anthropogenic factors on the quantity of the groundwater resource.

*Ecosystem Objective*

The capacity of groundwater discharge to maintain in-stream conditions and aquatic habitat at, or near potential is not compromised by anthropogenic factors.

*Endpoint*

Deviations in the base flow characteristics of sub-watersheds are not attributable to anthropogenic factors.

*Features*

Base flow is the more slowly varying component of total stream flow and is often attributed to groundwater discharge to wetlands, lakes, and rivers. Base flow is determined from total stream flow data using mathematical algorithms. Unlike point measurements of groundwater levels, base flow is an integrated measure of groundwater conditions and impacts upstream of the stream flow gauge. Various anthropogenic factors can impact the base flow characteristics of a sub-watershed. For example, increasing extents of paved and other impermeable surfaces due to urban development can reduce recharge and therefore decrease base flow. In contrast, conveyance losses in municipal water and wastewater systems can increase base flow. Anthropogenic factors in rural settings such as tile drainage and changes in vegetation coverage can impact base flow. The withdrawal of groundwater by pumping or through the drainage of quarries and other excavations can also impact base flow. Natural factors such as climate variability modify both average rates of base flow and the annual distribution of flow.

*Illustration*

Base flow indices are mapped by sub-watershed and plotted as time series. Temporal trends, where discernable, are mapped by sub-watershed.

*Limitations*

Stream flow monitoring of the full land mass is neither technologically nor economically feasible. Methods of determining base flow from total stream flow data are not standardized and the use of differing methods may produce inconsistent results. Differing summary statistics of base flow may also yield inconsistent results. Base flow is a delayed measure of changes in net infiltration (i.e., recharge due to precipitation less water withdrawal by pumping) and, in some settings, changes in this net rate due to anthropogenic factors may not be evident for extended periods of time. Water management practices such as flow regulation replicate base flow characteristics and disable the calculation of natural base flow in sub-watersheds where these practices are significant. Wastewater discharge similarly disables the calculation of natural base flow in sub-watersheds where this discharge is significant.

*Interpretation*
Statistical methods are used to detect changes in indices of base flow with respect to time. These methods are also used to differentiate natural (e.g., climatic) factors from anthropogenic factors as the cause of these changes.

*Comments*
None

*Relevancies*
Indicator Type: State
Environmental Compartment(s): water, land, biota
Related Issue(s): groundwater dependant ecosystems, climate change, land use
SOLEC Grouping(s): groundwater

*Last Revised*
July 18, 2002

Base Flow Due to Groundwater Discharge (sample report)
New Indicator

## Purpose

This indicator measures the contribution of base flow due to groundwater discharge to total stream flow by sub-watershed and is used to detect the impacts of anthropogenic factors on the quantity of the groundwater resource. Through most of the year, base flow forms only a proportion of streamflow, but in periods of drought it may represent nearly 100%, allowing the stream to continue to flow when precipitation recharge is insufficient.

## Ecosystem Objective

The goal for the base flow indicator is to be able to maintain in-stream conditions and aquatic habitat with natural base flow rates, without being compromised by human actions. Increasing withdrawals of groundwater due to population and industry expansion affect the amount of discharge entering streams, as water is diverted away from its natural course. Groundwater recharge may also be reduced due to hardening and compaction of the ground surface as paved surfaces are extended.

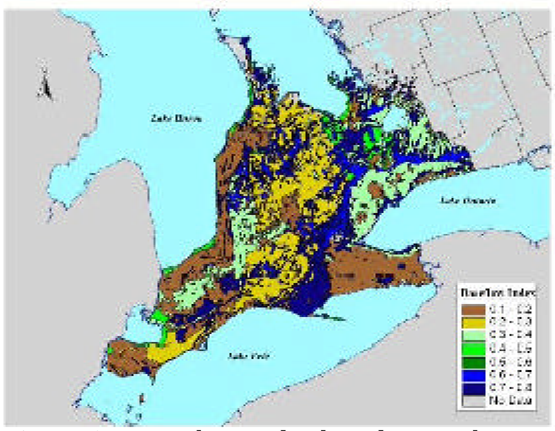

Figure 1. Base Flow Index based on geology
Source: Pigott et al, 2002

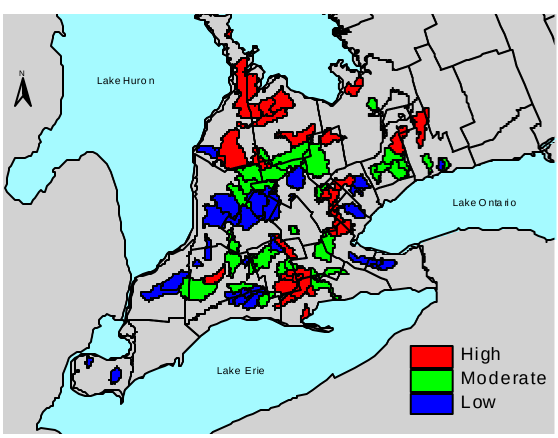


Figure 2. Base Flow Index calculated from stream gauge measurements
Source: Piggott et al, 2001

## State of the Ecosystem

The Base Flow Index (BFI), a measure of the rate of groundwater discharge relative to streamflow, may be calculated from stream hydrographs. The BFI indicates the percentage of streamflow that originated as groundwater. The groundwater contribution is dependant on several factors, including overburden and bedrock composition, and slope of the land surface.

The contribution of groundwater as base flow to the streamflow of rivers has been estimated to be about 40% across the Great Lakes basin. Calculations for base flow in Southern Ontario have estimated that groundwater contributes between 12 and 77 % to the streamflow in local watersheds. Figure 1 illustrates the distribution of base flow index, due mainly to local geologic influences. Other estimates, taken from actual streamflow gauges show similar predictions in Figure 2.

In the U.S., estimates have placed direct groundwater contributions highest in the Lake Michigan drainage area, at about 2,700ft$^3$/s. This is due mainly to the large number of sand and gravel aquifers located on, or close to the shoreline. Lake Michigan's streams also contribute the highest percentage of groundwater to the lakes, making up

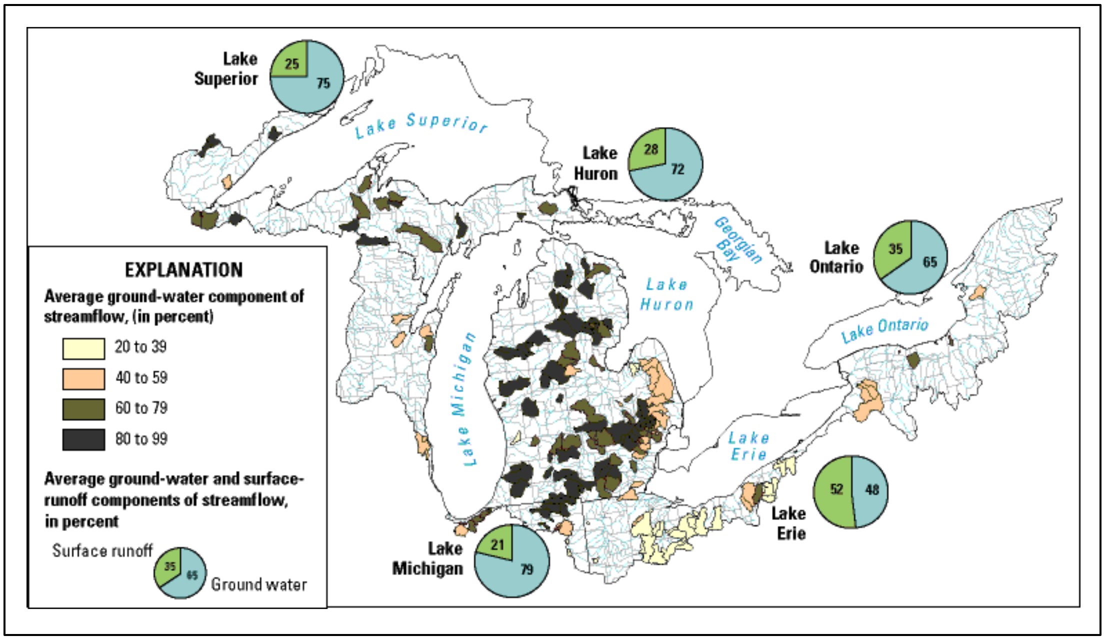


Figure 3. Base flow component of streamflow
Source: Grannemann et al, 2000

almost 80% of the streamflow. Figure 3 illustrates the base flow contribution for the entire basin, from the lowest to Lake Erie, at 48%, and highest to Lake Michigan, at 79%.

Future Pressures
Recent predictions have suggested that climate change could significantly impact groundwater resources of the Great Lakes. Changes in temperature and precipitation may impact total annual base flow and the distribution of this flow. For example, two different scenarios describing the climate of western southern Ontario at the end of this century result in a projected decrease in total annual base flow of 19 percent for the first scenario versus an increase of 3 percent for the second scenario. Projections based on the two scenarios suggest a consistent change in the annual distribution of this flow, with increased flow during the winter and decreased flow during the spring and early summer.

Further Action
Environment Canada and the Michigan District of the USGS are currently conducting an assessment of the contribution of groundwater discharge to stream flow within the Great Lakes basin. The study will involve the selection of a single method for the calculation of base flow due to groundwater discharge from stream flow information and the application of this method to data for gauged, near-natural United States and Canadian tributaries to the Great Lakes. Relations of the findings for these watersheds to characteristics of the landscape will enable discharge to be estimated for ungauged portions of the basin. Results of the assessment will provide a more complete description of the contribution of groundwater to the Great Lakes ecosystem and will be used by numerous agencies and stakeholder groups as a basis for land and water use planning.

Further Work Necessary
Research on the interactions of groundwater and surface water is sorely lacking at the moment. The 1999-2001 Priorities report to the IJC recommended further research on

groundwater discharge to surface water streams, and the estimation of natural recharge areas. In addition, research into the effects of climate change on groundwater and base flow contribution needs to be addressed, as the effects of climate change on the hydrology of the Great Lakes basin are uncertain. Although the Canadian and U.S. governments are starting to look at these areas, contributions from academia and the private sector could help address this priority.

Sources

This indicator was prepared using information from:

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Acknowledgments

Authors: Cheryl Martin, International Joint Commission, Windsor, ON and Andrew Piggott, Canadian Centre for Inland Waters, Burlington, ON.

Groundwater and Amphibian Communities
New Indicator

*Measure*
Presence of native cool water adapted frogs (mink frog and pickerel frog) and four salamander species (spring salamander, red salamander, two-lined salamander, four-toed salamander) from the lungless family Plethodontidae that have long-lived larval periods adapted to perennial flowing cool-cold groundwater springs and headwater streams.

*Purpose*
This bio-indicator metric will identify specific locations in a watershed where groundwater-fed habitats may be present. Where groundwater emerges to the land surface from a cold water table aquifer, a "spring" type aquatic habitat is formed. There are three general types of cold water-spring habitats:

(1) those that form a well-defined channel (rheocrene);
(2) those that form small pools or basins (limnocrene); and
(3) those that form a vegetated marsh, or swamp (heliocrene).

Cold water springs are unique freshwater ecosystems because their physical and chemical environments are relatively "stable" (low daily variance), although seasonal amplitude is present. The defining characteristics of spring-fed habitats are: (1) water is constantly present, and (2) the thermal environment is relatively cooler in summer months, and warmer in winter, compared to other aquatic habitats across the landscape that are not hydraulically connected to groundwater discharge. Loss of cold spring-fed groundwater habitats can threaten those species with stenothermic (narrow) temperature adaptations.

Two frog species (mink frog and pickerel frog), and the four-toed salamander, are associated with limnocrene and heliocrene types of cold water spring-fed wetland habitats in the Great Lakes basin. The three other salamander species (spring salamander, red salamander, two-lined salamander) are found in very small primary headwater streams that are the origin of larger cold water streams with native fish species (i.e., trout and sculpin type streams). Salamander species move higher into the headwater stream network than fish, forming what can be viewed as a 'salamander region' within the headwater streams of nature. The presence of salamander species with long-lived larval periods (2-5 years) can be used to provide a rapid assessment that cold groundwater flow is present. All four of the proposed salamander bio-indicators have extended larval periods, lasting from 2 to 4 years in duration.

*Ecosystem Objective*
The "river continuum concept" proposes that the trophic dynamics and integrity of larger streams is based on biological, chemical, and hydrological processes that occur in the smaller headwater streams that feed them. Cold groundwater is the primary source of flowing water found in most perennial flowing streams that have a healthy population of cold water adapted fish. However, not all headwater streams in a watershed are fed by groundwater, many become intermittent or ephemeral in summer months. The identification of cold groundwater-fed headwater streams would provide useful information for the development of watershed management plans that seek to protect groundwater sources, and the integrity of the downstream cold water ecosystems.

The newly emerging ecological concept of the "landscape" identifies two operational units, the "patch" and the "corridor", which are imbedded within a background "matrix" of physical-biological structure. Cold spring-fed habitats that emerge at the surface are called rheocrenes, limnocrenes, and heliocrenes and are unique types of groundwater dominated landscape patches and corridors.

*Endpoint*
To be established

*Features*
The presence of frogs will be determined based on either visual observation of adults, collections of tadpoles, or vocal calls. For salamanders, efforts will focus on field documentation of salamander "reproductive potential" such as larvae, egg clutches, or a good mix of juveniles and adults. A table listing specific frog and salamander species found in the Great Lakes basin that can be used as bio-indicators of cold groundwater-fed headwater streams will be provided.

*Illustrations*
A map of the Great Lakes basin with the geographic distribution of the 2 frog species and 4 salamander species will be provided. Together, the six amphibian bio-indicator species will be shown to cover the entire watershed for the Great Lakes basin.

*Limitations*
Use of this indicator depends on experience collecting frogs and stream salamanders, especially larvae. Thus it will be recommended that a combination of qualitative (visual search, vocal calls) and quantitative (leaf bags for salamander larvae, funnel traps for frog tadpoles) sampling methods be used to assess each habitat.

*Interpretation*
None identified at this time. However, it may be possible to overlap field information gained from biological sampling with GIS based mapping of geologic features such as depth to bedrock to predict the potential location of groundwater-fed headwater streams.

This amphibian indicator could be combined with other bio-indicators (cold water fish, plants such as mosses, diatoms, benthic macroinvertebrates, crayfish, etc.) to identify the presence of cool-cold water groundwater-fed habitats types. In addition, the various biological taxa could be combined to form an "Index of Ecological Integrity" of cold water habitats with groundwater intrusions for the Great Lakes.

*Relevancies*
Indicator type: State
Environmental Compartment(s): water, land, biota
Related Issue(s): land use, fish habitat
SOLEC Group: groundwater
GLWQA Annexes: 1, 11, 13, 16

*Last Revised*
July 18, 2002

Groundwater Dependant Animal and Plant Communities
New Indicator

*Measure*
Numbers and diversity of native invertebrates, fish, wildlife and plant communities dependent on groundwater discharges in tributaries and near shore areas of the Great Lakes.

*Purpose*
Indicator will assess locations of groundwater intrusions, support measuring of the contribution of groundwater to stream and near shore flows, and contribute to evaluation of trophic status, food web dynamics, and location of fish, wildlife and plant communities at risk in the Great Lakes basin. By inference, this indicator will also describe certain chemical and physical parameters of groundwater, including changes in patterns of seasonal flows.

*Ecosystem Objective*
Purpose of the GLWQA is 'to restore and maintain the chemical, physical and biological integrity of the Great Lakes'. Loss of quality and quantity of groundwater in Basin threatens sustained use, and may cause deterioration of drinking water quality for animals and humans and productive capacity of fauna and flora dependent on groundwater resources. Indicator supports Annexes 1, 2, 10, 11, 12, 16 of the GLWQA and Fish Community Goals and Objectives by Great Lakes Fishery Commission.

*Endpoint*
[DRAFT: pre-selected reference species occur at a test site OR pre-selected species composition occurs at test site OR biomass/production of the selected species/composition is within normal range [mean plus two SD] of same parameter measured at selected reference sites.]

*Features*
The diversity be reported by indices, &/or by biomass, &/or presence/absence of selected species or compositions e.g. brook trout, mottled and slimey sculpins, brook lamprey, selected aquatic insects [e.g. mayflies, stoneflies, caddis flies], cedar groves, watercress.

*Illustration*
For selected watersheds and sub-watersheds, and selected years, changes in species diversity, relative abundance, biomasses, and distribution would be graphed as surrogate for changes in groundwater quantity, quality and special distribution.

*Limitation*
Selection of other species to complete description of aquatic community in coldwater and to assess cool water environments may be necessary. Invertebrate and amphibian species need to be selected basin-wide.

*Interpretation*
More data analyses after modeling of different monitoring networks e.g. well water and fish distributions, plus research, are essential to using existing databases, and making monitoring programs efficient.

*Relevancies*
Indicator type: State
Environmental Compartment(s): water, land, biota
Related Issue(s): habitat, drinking water, land-use

SOLEC Groupings
GLWQA Annexes: 1, 2, 10, 11, 12, 16
IJC Desired Outcome(s): 6:Biological integrity and diversity; 9:Physical environment integrity groundwater
Beneficial Use Impairments: Restrictions on drinking water consumption; loss of fish and wildlife habitat

*Last Revised*
July 1, 2002

## Land Use and Intensity
New Indicator

*Measure*
Land use and land use intensity.

*Purpose*
This indicator measures land use and intensity within political sub-divisions (e.g. county, municipality...) and is used to infer the potential impacts of these practices on the quantity and quality of the groundwater resource.

*Ecosystem Objective*
Groundwater quantity and quality remain at, or near, natural conditions.

*Endpoint*
Monitoring of groundwater quantity and quality in the most stressed of the sub-divisions does not detect the deterioration of these conditions.

*Features*
Land use is a measure of the primary use of the land (e.g., percentage of a sub-division occupied by livestock feedlot operations) and land use intensity is the intensity of this use (e.g., head of feedlot cattle per hectare). The reference political sub-divisions should be sufficiently large to ensure the availability of data and sufficiently small to ensure that contrasts in the potential impacts are not masked by averaging.

*Illustration*
Land use and intensity, and changes in these practices over time, are mapped by sub-division.

*Limitations*
Methodologies for the determination of land use and intensity using remotely sensed and census data are presently under development and testing. Changes in these indicators can be determined with no greater frequency than that of the collection of the required data and it is unlikely that extensive historical information can be derived. The sustainability of prevailing land use and intensity relative to the groundwater resource is not currently known with certainty in all settings.

*Interpretation*
Statistical methods are used to detect changes in land use and intensity over time.

*Comments*
Land use and intensity, water use and intensity, and the characteristics of the groundwater resource are interrelated. Water use within a sub-division is dependent on the distribution of land uses within the sub-division. Likewise, the intensity of water use is dependent on land use and intensity. Land uses associated with high water use intensities, or with more stringent water quality requirements, are likely to be restricted in areas where the natural quantity or quality of the groundwater resource are limited.

*Relevancies*
Indicator Type: pressure
Environmental Compartment(s): water, land

Related Issue(s): land use, agriculture, forestry
SOLEC Grouping(s): groundwater, land use

*Last Revised*
July 18, 2002

Managing the Groundwater Resource
New Indicator

*Measure*
There is progress toward developing the background information that is required to manage groundwater resources.

*Purpose*
This indicator is a measure of the availability of the information that is required for the sound management of the groundwater resource and an accounting of the number of new and existing groundwater programs that are in place.

*Ecosystem Objective*
The capacity of the groundwater resource to function societally as a water supply and ecologically in the maintenance of aquatic habitat is protected through the application of sound management practices.

*Endpoint*
Land and water management agencies respond to issues in a manner that is not restricted by the availability of groundwater related information.

*Features*
The results of groundwater related studies conducted using public funding are adequate; maintained; indexed by location, time frame, and issue; and are broadly available but subject, where required, to licensing and cost recovery. Basic and applied groundwater related research performed using public funding is adequate and relevant, both geographically and by issue. Groundwater related monitoring programs are adequate and are routinely assessed and revised to resolve gaps in data collection and to respond to emerging issues. Land and water management agencies are aware of the importance of including groundwater as a central component of their practice. Policy makers and the public understand the nature of the resource, the societal and ecological functions of groundwater, and their role in protecting the resource.

*Illustration*
A survey of land and water managers could pose a true or false statement such as “There is obvious progress toward developing the background information required to manage our groundwater resource.”

*Limitations*
Certain tasks associated with the creation of groundwater related information (e.g., baseline monitoring and hydrogeological mapping) require extended periods of time for completion. Tangible progress toward the creation of this information is adequate for the purpose of this indicator. Programs that are already in place may not adequately protect or manage groundwater resources.

*Interpretation*
Land and water management agencies achieve a consensus that either adequate groundwater related information is available or that a feasible plan is in place for the generation of this information.

*Comments*
None.

*Relevancies*
Indicator Type: Response
Environmental Compartment(s): water
SOLEC Grouping(s): groundwater, societal response

*Last Revised*
July 18, 2002

Natural Groundwater Quality and Human-Induced Changes (description)
New Indicator

*Measure*
Groundwater quality as determined by the natural chemistry of the bedrock or overburden, and the concentrations of anthropogenic contaminants such as pesticides, nitrates, pathogens and urban pollutants.

*Purpose*
This indicator will assess the quality of groundwater for both drinking water and agricultural purposes, and for ecosystem functions. The consumption of groundwater that is degraded in quality may lead to both animal and human health effects. It may also indicate where contamination is occurring, and where programs for remediation and prevention of non-point contamination should be focused.

*Ecosystem Objective*
The quality of groundwater will remain at, or approach, natural conditions.

*Endpoint*
To be established.

*Features*
Significant variability of natural groundwater chemistry occurs throughout the basin, however, little variability should occur within hydrogeologic units. Changes in groundwater quality due to anthropogenic activity will indicate the quality of groundwater for human consumption. This indicator should work in conjunction with the Drinking Water Quality Indicator, #4175.

*Illustration*
Maps showing the natural base chemistry of the U.S. states and province of Ontario could be produced. Additional maps could show the locations of contaminated wells, either in total or for specific types of contamination or areas that are vulnerable to contamination

*Limitations*
Programs to sample both the natural and contaminated quality of groundwater are already present in all eight states and Ontario; however, they are not currently comparable on all levels. Collaboration between federal, state and provincial agencies could produce a sampling protocol that would make all programs comparable. Several national programs exist in the U.S. that are implemented in all the eight states, but sampling sites are too few to be adequate.

Also, groundwater quality sampling of ambient wells unaffected by human activities is necessary to evaluate the natural chemistry. In some areas ambient sampling has not been done, and if contamination has occurred, natural chemistry may not be evaluated effectively.

*Interpretation*
Information relating water use rates may be required to evaluate whether the contamination of groundwater supplies will affect human health. Groundwater in areas of low to non-existent consumption may remain contaminated with little harm to humans. Still, the sensitivity of aquatic ecosystems to groundwater contamination should not be overlooked, as the effects will increase significantly in areas where groundwater discharge is a large compo-

nent of stream flow.

*Comments*
None.

*Relevancies*
Indicator Type: Pressure
Environmental Compartment(s): water, land
Related Issue(s): drinking water, land-use, fish habitat
SOLEC Groupings:
GLWQA Annexes: 1, 11, 13, 16

*Last Revised*
July 11, 2002

Natural Groundwater Quality and Human-Induced Changes (sample report)
New Indicator

## Purpose

This indicator will assess the quality of groundwater for drinking water and agricultural purposes, and for ecosystem functions. The consumption of groundwater that is degraded in quality may lead to both animal and human health effects. This indicator may also reveal areas where contamination is occurring, and where programs for remediation and prevention of non-point contamination should be focused.

## Ecosystem Objective

Protection and maintenance of groundwater sources to meet Canadian and U.S. drinking water standards is necessary to ensure a safe supply for all. Although some groundwater supplies within the basin are already contaminated, either by human activities or through natural processes, it is hoped the quality will remain at, or approach, natural conditions.

## State of the Ecosystem

The quality of groundwater in the Great Lakes basin is varied, ranging from excellent to poor quality and unfit for consumption.  Differences may be dependant on natural factors, such as bedrock, or overburden composition, or influenced by human activities. Land-use practices such as agriculture, urban living and industry have unique imprints on local groundwater supplies, such that water quality testing should reflect those activities taking place locally.

Several areas in the Great Lakes basin contain groundwater that naturally exceeds drinking water guidelines for substances such as arsenic and radon. Figure1 illustrates areas in the U.S. that have arsenic-contaminated groundwater. Areas of the Great Lakes such as the western sides of Lake Michigan and Lake St Clair contain groundwater that exceeds the current EPA limit of 50ug/L. It is expected that the number of exceedances will rise considerably once the new arsenic guideline of 10mg/L becomes effective January 23, 2006.

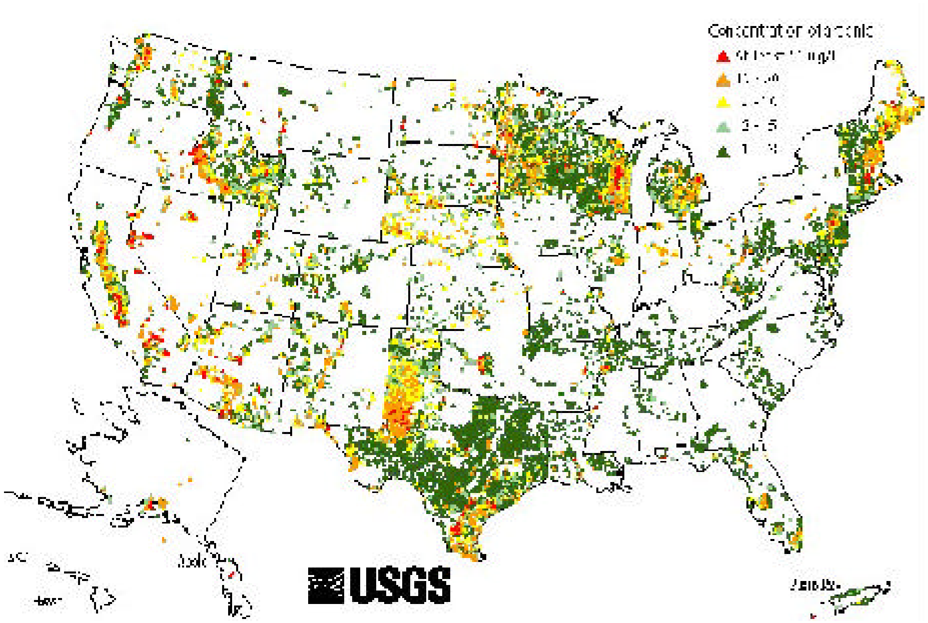



Figure 1. Arsenic in Groundwater of the U.S.

Groundwater contamination has been shown to be most prevalent in shallow groundwater less than 100 feet below agricultural and urban areas. In a survey of Ontario’s rural groundwater quality in 1992, 36 % of the 1292 wells tested exceeded the Maximum Allowable Concentration for coliform bacteria.

In May 2000, an episode of groundwater contamination with coliform bacteria, specifically E.coli from a feedlot, resulted in the deaths of 7 Walkerton, Ontario residents and illness in over 2000 others.

In the same Ontario survey, 14% of the farm wells had samples that exceeded the drinking water objective for nitrates. Contamination of drinking water with levels of nitrates above the objective of 10mg/L can lead to methemoglobinemia, or "blue baby syndrome" in infants under six months of age.

Although not as common, pesticides may also leach into soil, causing groundwater contamination. Figure 2 shows atrazine contamination of groundwaters in Wisconsin, in relation to bedrock composition. The biggest concern with pesticide contamination is that the majority of pesticides and their breakdown products do not have a determined MACL or limit above which human life is threatened by consumption of contaminated waters.

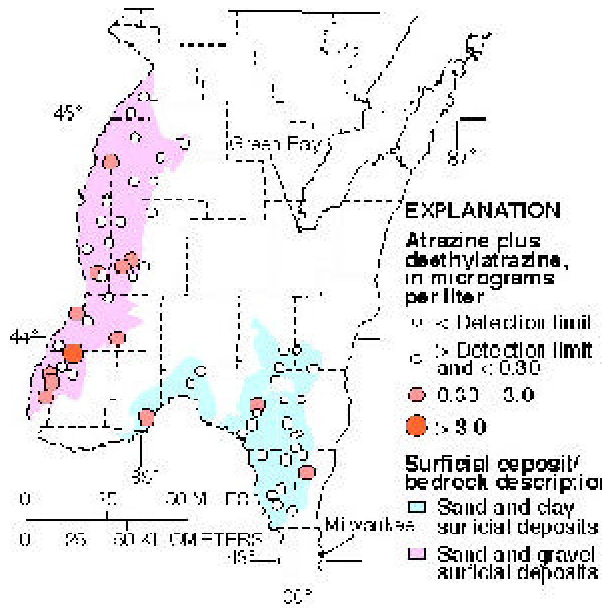



Figure 2. Atrazine concentrations in shallow groundwater were highest in areas with the most permeable surficial deposits.
Source: USGS Circular 1156, 1998.

Trends in rural and agriculturally influenced groundwater indicate that nitrate levels are stable, but that bacterial contamination is increasing. Relative to bacterial levels determined in 1950 to 1954, the 1992 Ontario survey indicated a 45% increase in contaminated rural groundwater.

Urban areas are subject to different types of groundwater contamination. Salts used for de-icing roads, airplanes and runways have been found at extremely high levels in the groundwater of the Greater Toronto Area, in the range of 10 to 60 times as high as natural concentration. More than 11 million tons of salt are applied to roads in the Unites States annually, while, approximately 25-50% of this salt is leached into groundwater. Other sources of contamination include leaking underground storage tanks, chemical spills, lawn fertilizers and improperly disposed waste products.

## Future Pressures on the Ecosystem

As population grows and urban areas continue to expand into agricultural lands, pressure on the groundwater supply will increase. Intensification of agriculture will only amplify this pressure, and increasing the chance of contamination. Additionally, the effects of climate change on groundwater resources in the Great Lakes basin are presently unknown, but it is suggested that resources will decrease, and thus concentrating any contamination already present.

## Future Action

The implementation of Best Management Practices and other nutrient and pesticide control plans in farms will help to educate farmers about the potential health hazards and economic benefits to be gained from groundwater protection. Groundwater protection plans should be required for all municipal groundwater users.

Further Work Necessary

Studies on groundwater in the Great Lakes are not adequate to determine the quality of our groundwater. Study and research is needed to determine the current state of the supply, and to estimate future impacts related to growth and climate change. Also, drinking water standards and water quality data must be standardized across the two countries.

Sources

This indicator was prepared using information from:

Rudolph, D and M. Goss, 1993. Ontario Farm Groundwater Quality Survey. For Agriculture Canada.

USGS Circular 1156. 1998. Water Quality in the Western Lake Michigan Drainages, Wisconsin and Michigan, 1992-1995.

USGS and National Water Quality Assessment publication, Arsenic in Groundwater of the U.S.

Acknowledgments

Author: Cheryl Martin, International Joint Commission, Windsor.

Water Use and Intensity (description)
New Indicator

*Measure*
Water use and water use intensity.

*Purpose*
This indicator measures water use and intensity within political sub-divisions (e.g. county, municipality...) and is used to infer the potential impacts of these practices on the quantity and quality of the groundwater resource. The indicator also measures supply versus demand issues by assessing the reconstruction of water wells.

*Ecosystem Objective*
Groundwater quantity and quality remain at, or near, natural conditions.

*Endpoint*
Monitoring of groundwater quantity and quality in the most stressed of the sub-divisions does not detect the deterioration of these conditions.

*Features*
Water use is a measure of the primary use of all constructed water wells (e.g., the percentage of all wells that are constructed for livestock watering) and water use intensity is the intensity of withdrawals from these wells (e.g., the equivalent annual depth of water use for livestock watering). The intra-annual variability of water use intensity is also significant. For example, municipal water use is modestly variable during the year while the use of water for livestock is more temperature dependent and the use of water for irrigation is episodic. The reference political sub-divisions should be sufficiently large to ensure the availability of data and sufficiently small to ensure that contrasts in the potential impacts are not masked by averaging. Water use that is consumptive (e.g., irrigation) can result in diminished base flows and impacts on downstream water supplies and aquatic habitat. Water use that is not consumptive (e.g., the drainage of quarries) can result in the degradation of water quality. Supply versus demand issues are expressed in the reconstruction of water wells; for example, in the deepening of existing wells or replacement of existing wells with a larger capacity wells. Patterns in this practice may indicate a diminished supply due to climatic factors or adjacent land or water use, an increased demand at the well, and variations in the quality of the supply or the quality requirements of the demand. All of these causes may be evidence of changes in the sustainability of the groundwater resource.

*Illustration*
Water use and intensity, changes in these practices over time, and supply versus demand issues are mapped by sub-division.

*Limitations*
Water use can be measured using data such as water well construction records and permits to take water. These data may be adequate to measure both current and historical practices and therefore changes over time. However, not all uses and users of water are captured in these data sets. The sustainability of prevailing water use and intensity relative to the groundwater resource is not currently known with certainty in all settings. Water well construction information does not include the reason for the reconstruction of a well, which therefore must be determined from other supporting data.

*Interpretation*
Statistical methods are used to detect changes in water use and intensity over time and to identify patterns in supply versus demand issues.

*Comments*
Land use and intensity, water use and intensity, and the characteristics of the groundwater resource are interrelated. Water use within a sub-division is dependent on the distribution of land uses within the sub-division. Likewise, the intensity of water use is dependent on land use and intensity. Land uses associated with high water use intensities, or with more stringent water quality requirements, are likely to be restricted in areas where the natural quantity or quality of the groundwater resource are limited.

*Relevancies*
Indicator Type: Pressure
Environmental Compartment(s): water, land
Related Issue(s): drinking water, land use
SOLEC Group: groundwater

*Last Revised*
August 20, 2002

Water Use and Intensity (sample report)
New Indicator

Purpose
This indicator measures water use and intensity within political sub-divisions and is used to infer the potential impacts of these practices on the quantity and quality of the groundwater resource. The indicator also measures supply versus demand issues by assessing the reconstruction of water wells.

Ecosystem Objective
Some areas of the Great Lakes basin are experiencing population growth, and while increasing their groundwater withdrawals, are stressing the supply. Use of the groundwater resource should not lessen the supply of groundwater, and be managed effectively within the available sustainable supply.

State of the Ecosystem
Water use is measured for the primary use of groundwater withdrawals from all constructed water wells, and water use intensity as the quantity of withdrawals from these wells in a specified time interval (e.g. $m^3$/day). During the period from 1950 to 1980, the total withdrawal of surface water and ground water in the U.S. continually increased, however, after 1980 water withdrawals declined and have remained fairly constant. In 1995, total groundwater withdrawals for the United States were 77,500 Mgal/day.

As shown in Figure 1, water use along the shorelines of the Great Lakes is mainly from surface water. Groundwater use becomes more important the farther away the community is from the Great Lakes. Urban areas such as Kitchener and Waterloo, Ontario rely on groundwater to supplement the limited amount of water they can remove from surface water sources like the Grand River. Some States within the Great Lakes basin rely heavily on groundwater, with about half of all Michigan cities and townships relying on private and city wells for their supply.

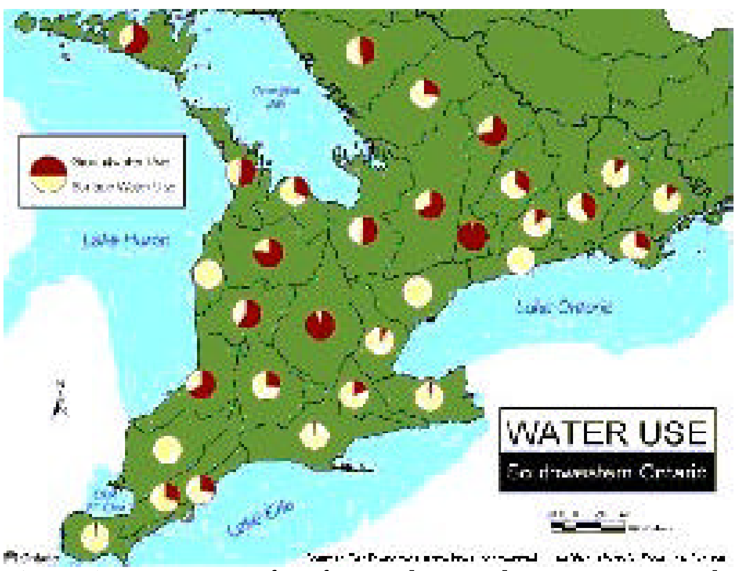


Figure 1. Percentage of surface and groundwater use in Southern Ontario watersheds
Source: Environment Canada, Water Use and Supply Project

Water Use is divided into different sectors, such as domestic, industrial and commercial, to show how much water, especially groundwater, is used in each. Significant differences in water use between Michigan (Figure 2) and Wisconsin (Figure 3) are seen in the areas of domestic, irrigational and industrial supply. These differences result from differences in land use, as Michigan has a greater industrial sector and several densely populated areas, while Wisconsin relies more on agricultural practices. Rural areas often use more groundwater per capita than urban areas, as they are often farther from surface water sources and lack the necessary water distribution networks.

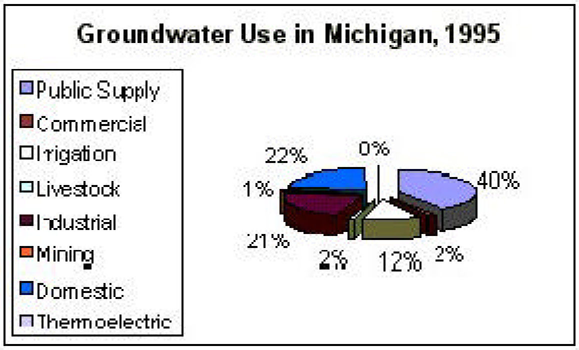



Figure 2. Percentage of groundwater use by sector for Michigan, 1995
Adapted from: Solley et al, 1998

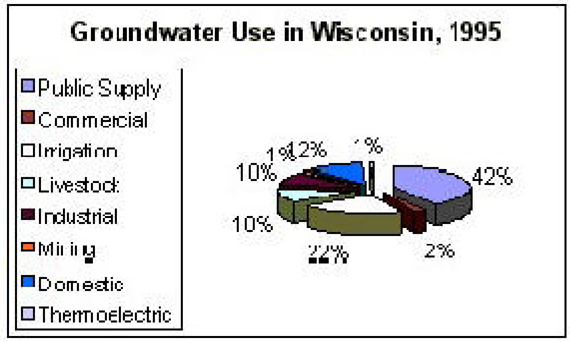



Figure 3. Percentage of groundwater use by sector for Wisconsin, 1995
Adapted from: Solley et al, 1998

Other differences in groundwater use may result from changing seasons. For example, municipal water use is relatively constant, while the use of water for irrigation is episodic. Consumptive water use, such as irrigation, can result in diminished base flows and impacts on downstream water supplies and aquatic habitat.

Recent summers in the Great Lakes region have seen lower than average amounts of rainfall and record temperatures, resulting in a sharp decline in the amount of water replenishing some underground wells. Consequently, some well owners have had to dig deeper to restore well yield and/or quality, while others have had to dig entirely new wells. Wells showing a decrease in supply may be affected by climatic factors or adjacent land or water use, an increased demand at the well, and variations in the quality of the supply or the quality requirements of the demand. Figure 4 illustrates how groundwater supply and recharge may be changed when demand exceeds supply. Withdrawals in the Chicago area have reduced the water level and moved the groundwater divide over 50 miles in some areas, drastically changing flow patterns.

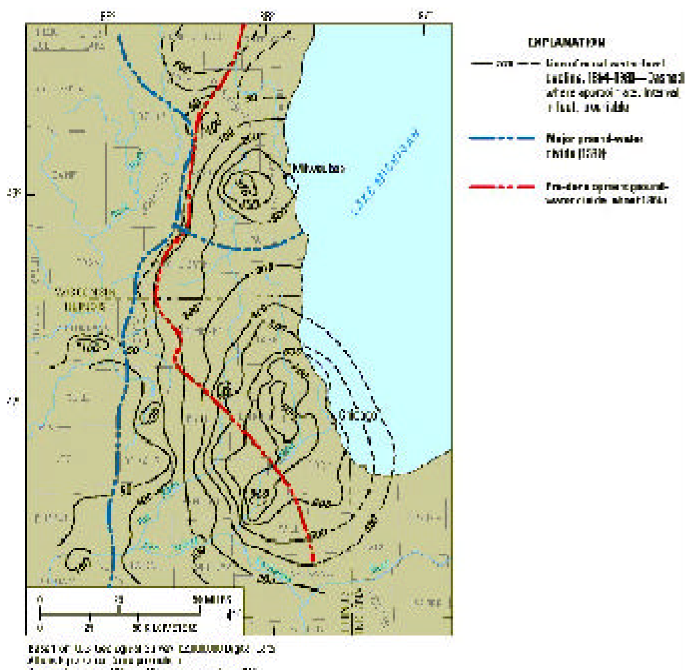



Figure 4. Changes to groundwater in the Chicago area, 1864-1980.
Source: Grannemann et al, 2000

Future Pressures

Population growth and urban sprawl continue to place pressure on the groundwater supply. Water distribution networks do not exist in new developments, and they are expensive to build, so new residents often tap into the groundwater, which may affect current users of the supply. It has been predicted that climate change will affect the recharge of groundwater, with increases in winter recharge and decreases in summer. It is not known how these changes will affect the available supply.

Further Action

The effects of groundwater withdrawals on the hydrologic cycle can only be examined if there is an understanding about the interaction of groundwater and surface water. Thus, studies are needed to quantify and describe this relationship, especially in the Great Lakes basin. Additionally, public supply systems need to realize the value of demand management of groundwater resources, rather that the old standard of supply management. Because our supplies are limited, it only makes sense to control our water use by reducing our withdrawals and lessening the impacts. By using water saving devices and charging less for water used during non-peak time periods, we can reduce or water use by up to 35 percent.

Sources

This indicator was prepared using information from:

Environment Canada, Water Use and Supply Project. Communication with Wendy Leger.

Grannemann, N.G., Hunt, R.J., Nicholas, J.R., Reilly, T.E. and T.C. Winter. 2000. The Importance of Groundwater in the Great Lakes Region. USGS Water-Resources Investigations Report 00-4008.

Solley, W.B., Pierce, R.R. and H.A. Perlman. 1998. Estimated use of water in the United States in 1995. USGS Circular 1200.

Acknowledgments

Authors: Cheryl Martin, International Joint Commission, Windsor, ON and Andrew Piggott, Canadian Centre for Inland Waters, Burlington, ON.

# 8. Other Proposed Indicators

A few other indicators have been proposed for inclusion in the Great Lakes indicator suite. These are: Contaminants in Whole Fish, Lake Sturgeon, Non-native Species and Crop Heat Units. They have been proposed to fill smaller gaps in the suite of indicators.

Contaminants in Whole Fish was overlooked during the first iteration of the Great Lakes indicator suite. However, it has been deemed to be necessary for inclusion in the suite. This proposed indicator also has a sample indicator report.

Lake Sturgeon is proposed as an indicator of the health of the ecosystem. It is a long-lived fish species that was abundant in the Great Lakes at the time of European settlement.

Unfortunately the indicator description for Non-native Species is unavailable at this time, but will be prepared and available for comment shortly after SOLEC 2002.

Crop Heat Units is being proposed to replace the current indicator Extreme Storms. They are both indicators of Climate Change and the descriptions for each have been included in this section for ease of comparison and discussion.

Contaminants in Whole Fish (description)
Indicator ID: #121

*Measure*
Concentration of persistent, bioaccumulating, toxic (PBT) chemicals in Great Lakes whole lake trout and walleye (and major prey species).

*Purpose*
To assess trends in the concentration of PBT chemicals in the open waters of the Great Lakes using fish as biomonitors, as a measure of the success of remedial actions and to infer real or potential effects of contaminants on fish, fish-consuming wildlife and human consumers of sport fish species.

*Ecosystem Objective*
Great Lakes waters should be free from materials will produce conditions that are toxic or harmful to human, animal or aquatic life (GLWQA General Objective). This indicator supports Annexes 1, 2, 11 and 12 of the GLWQA.

*Endpoint*
Reduction in concentration of PBT chemicals in whole fish to levels that do not pose a risk to the health of Great Lakes fish populations or to fish-eating wildlife populations or potential effects to human consumers of sport fish species.

*Features*
The temporal and geographic trends in the chemical contaminant levels in lake trout from Lakes Ontario, Huron, Michigan and Superior, and walleye from Lake Erie will be used as an indicator of exposure to PBT chemicals in the water and food web. Fish will be collected in the fall of the year, not less frequent than every other year. Using fish of similar size reduces the impact of size variation on contaminant trend data. Individual whole fish are analysed to provide data on the spectrum of bioavailable contaminants present in Great Lakes aquatic ecosystems. Organochlorine contaminants to be measured include PCBs, DDT and metabolites, dieldrin, toxaphene, chlordanes, nonachlors, and other recently detected compounds that may be of concern. Trace metals chosen for monitoring will include Hg, Pb, Cu, Ni, Zn, Cd, Cr, As, and Se. Selection will depend on local environmental conditions. Data will be statistically analysed (by age or size cohort) to determine mean and variance for each species, chemical, lake and year.

*Illustration*
Bar graphs, line graphs and/or scatter plots may be used to show trends over time for each species (by age or size cohort), chemical and lake.

*Limitations*
Consistency is very important to conduct trend analyses. Over time, fish of similar size/age should be collected, contaminants monitored should be consistent, and specific analytical techniques used must be comparable to those used in the past. Caution is warrented if data from more than one jurisdiction or monitoring program are used to evaluate temporal or spatial trends. Data collected under different sample treatment or chemical analyses protocols may be incompatible in some cases. Contaminant concentrations in whole fish are routinely higher than in the edible portions. Therefore, the data may not be directly appropriate for assessing the need for fish consumption advisories to protect human health. The utility of these whole fish data are that they provide a more sensitive indicator of emerging

contaminant issues such as the detection of recently identified contaminants or the increase in concentrations of a previously regulated contaminant.

*Interpretation*
Reductions in contaminant levels in whole fish will reflect environmental change, i.e. reductions in contaminant loading with subsequent reductions in the concentration of contaminants in the water or changes in the food web composition, and will pose less risk of harm to fish communities, fish-eating wildlife and human consumers of Great Lakes fish.

*Comments*

*Unfinished Business*
Should identify quantitative endpoints for each contaminant to be protective of aquatic life and fish-consuming wildlife.

*Relevancies*
Indicator Type: pressure
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): open 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): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 3.Degradation of fish and wildlife populations

*Last Revised*
May 1, 2002

Contaminants in Whole Fish (sample report)
Indicator ID: #121

Purpose
Annual or biennial analysis of contaminant burdens in representative fish species from throughout the Great Lakes provides data to describe temporal and spatial trends of bioavailable contaminants which is a measure of both the effectiveness of remedial actions related to the management of critical pollutants and an indicator of emerging problems.

Ecosystem Objective
Great Lakes waters should be free of toxic substances that are harmful to fish and wildlife populations and the consumers of these biota. Data on status and trends of contaminant conditions, using fish as biological indicators, supports the requirements of GLWQA Annexes 1, (Specific Objectives) 2, (Lakewide Management Plans/Remedial Action Plans) 11, Surveillance & Monitoring and Annex 12, Persistent Toxic Substances.

State of the Ecosystem
Long-term (>25 yrs), basin wide monitoring programs measuring whole body levels of a variety of contaminants in top predator lake trout or walleye and forage fish species (i.e. smelt) have provided temporal and spatial trend data on bioavailable toxic substances in the Great Lakes aquatic ecosystem. The Canadian Department of Fisheries and Oceans measures contaminant burdens annually in similarly aged fish, and the U.S.Environmental Protection Agency measures contaminant burdens biennially in similarly sized fish. Since the late 1970's levels of historically regulated contaminants such as PCBs, DDT and Hg have generally declined in most fish species monitored. Some other contaminants, both currently regulated and unregulated, have demonstrated either slowing declines or, in some cases, increases in selected fish communities. The changes are often lake specific and relate both to the specific characteristics of the substances involved and the biological condition of the fish community surveyed.

Trends:

Lake Ontario - PCB and ΣDDT levels in lake trout have declined consistently through 2001 (Fig 1, 1A, 2, 2A). Levels of both PCBs and ΣDDT in smelt samples have declined significantly through 2001 since the most recent peak in 1997 (Figs 3 & 4). Concentrations of Hg in smelt populations have remained virtually unchanged since 1985 (Fig. 5).

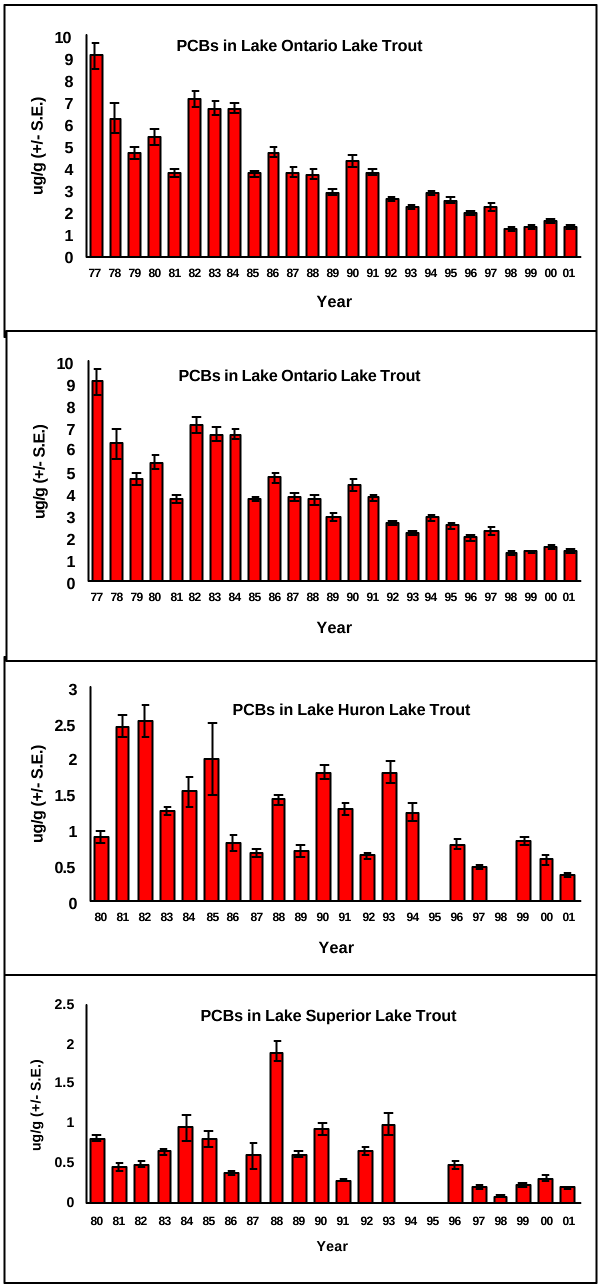
Lake Erie - PCB levels in lake trout ($4^+$ - $6^+$ age class) have declined consistently with levels measured in 2001 approximately 16% of those concentrations found in the same age class from 1993 (Fig 1). Modest increases in SDDT levels were observed in 2001 lake trout samples ($4^+$ - $6^+$) (Fig 2). PCB concentrations in walleye, have continued to increase over the period 1995 to 2001, but recent levels are still ~ 60% of those measured in similarly aged and/or sized fish in 1992 (Fig 1A, Fig 6). The Canadian data shows that SDDT levels in 2001 samples of walleye ($4^+$ - $6^+$) are 15% of maximum levels recorded in 1989 soon after the arrival of zebra mussels in Lake Erie (Fig. 7). U.S. data shows a similar trend for similarly sized walleye with 2000 SDDT levels approximately 23% of levels recorded in 1988 (Fig 2A). Total PCB and SDDT levels in smelt peaked in 1990 and 1989 respectively (Figs 3 & 4). Since then concentrations of both contaminants have steadily declined through 2001. Hg concentrations in smelt samples have seen a modest increase in the past 2 years; 2000 and 2001 (Fig 5).

Lake Huron – The U.S. data shows that PCBs in similarly sized fish have steadily declined through 2001 (Fig. 1A). ΣDDT in similarly sized fish showed large declines in the 1970s and 1980s with levels in the 1990s staying level at concentrations approximately 18% of 1979 levels (Fig. 2A). The Canadian data shows that for both PCBs and ΣDDT, as measured in lake trout ($4^+$ - $6^+$), concentrations have declined steadily through 2001 from the most recent peaks measured in 1993 similarly aged fish (Figs. 1 & 2). Similarly, most recent peak concentrations of PCB and ΣDDT, measured in 1994 and 1993 samples of smelt were followed by a period of steady decline in concentrations with 2001 levels the lowest in the past decade (Figs 3 & 4). Mercury levels in Lake Huron smelt populations have remained virtually unchanged since 1985 with 2001 concentrations <50% of maximum levels measured throughout a 24- year period (Fig. 5).

Lake Michigan - PCB and ΣDDT levels in lake trout have declined consistently through 2000 (Fig 1A & 2A). PCB levels in 2000 lake trout are approximately 8% of those found in similarly sized fish in 1974. Current ΣDDT levels are approximately 5% of concentrations found in similarly sized lake trout in 1970.

Lake Superior - Total PCB levels in Lake Superior lake trout are currently fluctuating from year to year and appear to be leveling off (Figs. 1& 1A). The U.S. lake trout data demonstrates initial declines in concentration from the 1970s with a leveling off starting in the late 1980s with current levels approximately 30% of maximum levels (Fig.1A). The Canadian data shows that PCB levels measured in a specific lake trout age class ($4^+$ - $6^+$), have fluctuated significantly over the past 6 years, but 2001 concentrations were ~ 20% of 1993 levels and 10% of 1988 maximum concentrations measured in this same age class of fish (Fig 1). The U.S. data for ΣDDT shows a similar pattern to its PCB data, with initial declines in the late 1970s and early 1980s and then a leveling off in the late 1980s to about 15% of maximum levels (Fig.2A). The Canadian data shows that ΣDDT levels for the $4^+$ - $6^+$ age class of lake trout have declined relatively constantly to a concentration in 2001 samples, which was < 20% of a recent maximum observed in 1993 samples (Fig 2). Apart from an anomalously high peak (> 1.0 µg/g) measured in smelt collections from 1988, total PCB levels have remained virtually unchanged through 2000 at levels of near 0.02 µg/g (Fig 3). Over the period 1981 to 2000, ΣDDT concentrations observed in smelt populations have remained unchanged since a significant decline occurred in 1984 (Fig. 4). An exception was a single year modest increase seen in 1998 samples. Mercury concentrations in Lake Superior smelt populations have exhibited a reasonably steady decline over the period 1981 through 1999 (Fig 5). There was a 6-year period, from 1988 through 1993, of increasing concentrations of Hg but levels measured from 1995 through 1999 were consistently lower.

Toxaphene levels measured in the Lake Superior lake trout community have either increased slightly or ceased to decline despite the fact that use of the compound has either been banned or its use severely restricted within the Great Lakes basin since the early 1980's (Whittle et al. 2000). Evidence suggests that declines in the abundance of smelt populations, subsequent diet shifts by lake trout to more contaminated lake herring and the increase in atmospheric deposition may have accounted for the trend in toxaphene burdens measured in Lake Superior. Similarly, in Lake Erie after the late 1980's invasion and proliferation of zebra and quagga mussels, contaminant levels measured in top predator walleye did increase for a short period of time. The influence of exotic dreissenid invaders such as zebra and quagga mussels, round gobys, Eurasian ruffe or invertebrate species such *Echinogamarus* or *Cercopagis* is to change the form and function of existing food webs (Morrison et al 1998, 2002). This change alters the food web energy dynamics plus pathways and fate of contaminants, which in turn can result in shifts in bioaccumulation patterns.



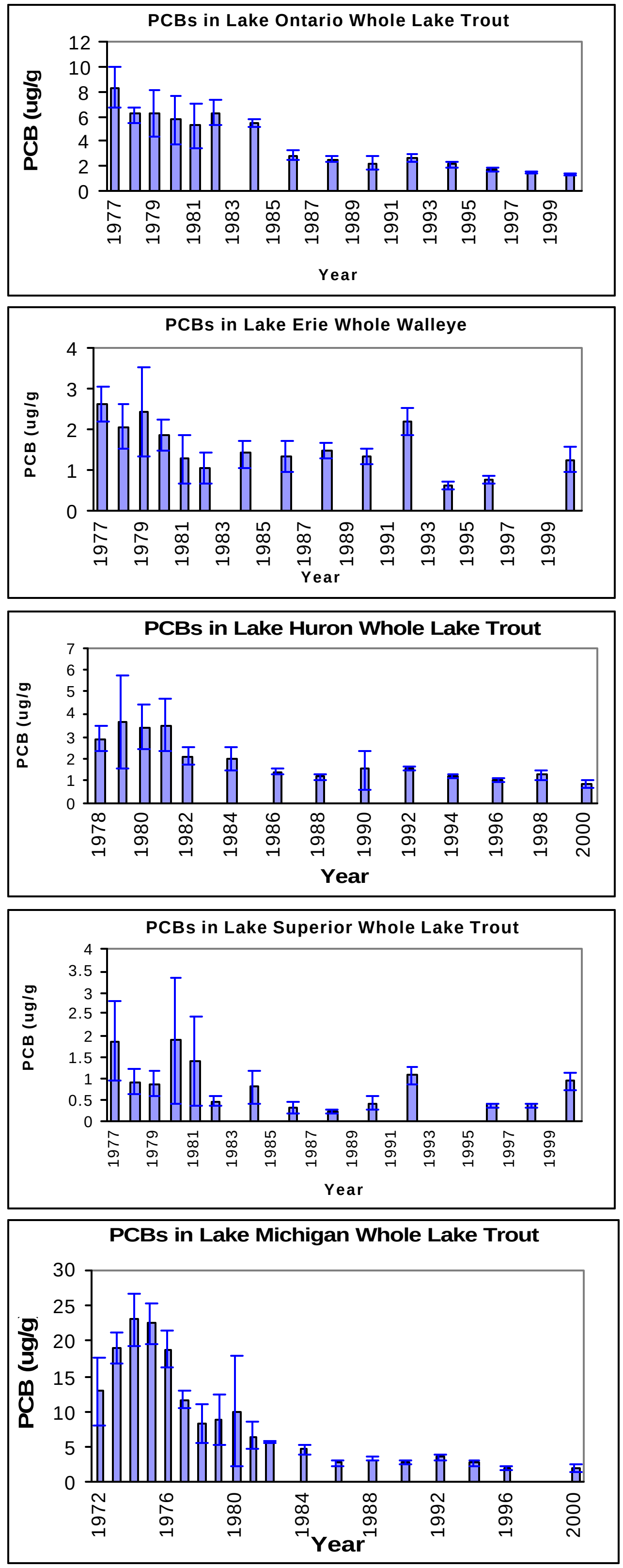




Figure 1. Total PCB Levels in Whole Lake Trout (1977-2001). (Canadian data ug/g wet weight +/- S.E., age 4+ - 6+ yrs)
Note the different scales between lakes.
Source: Department of Fisheries and Oceans Canada

Figure 1a. PCB Levels in Whole Lake Trout (1977-2001). (ug/g wet weight +/- 95% C.I., composite samples, 600-700 mm size range. Lake Erie data are for walleye in the 400-500 mm size range)
Note the different scales between lakes.
Source: U.S. Environmental Protection Agency

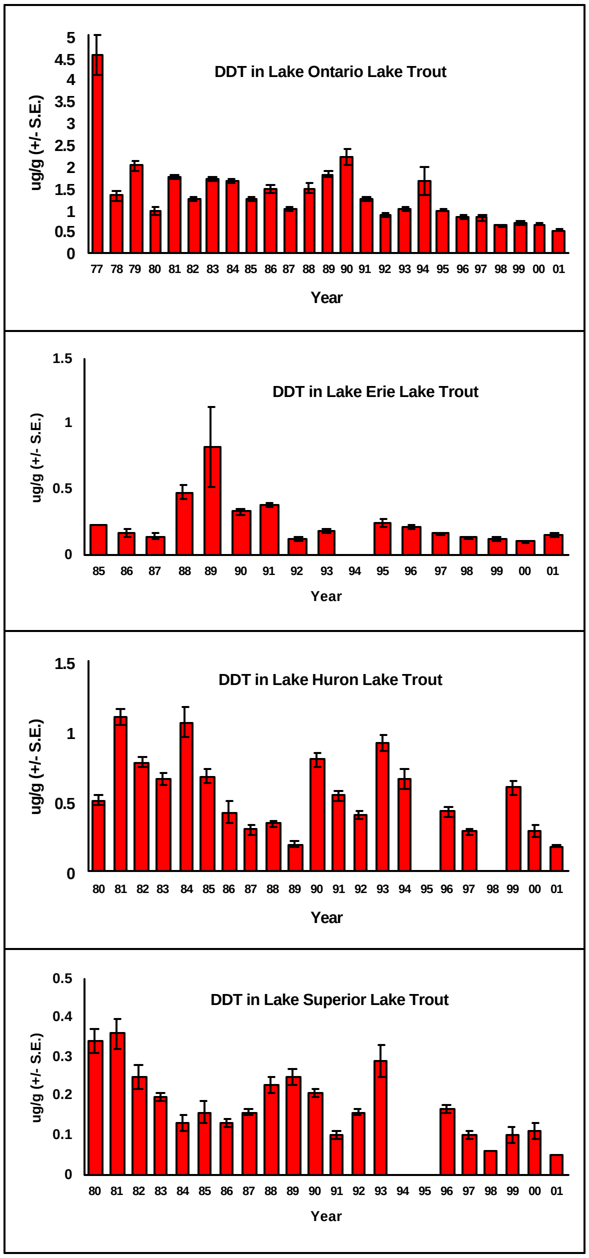



Figure 2. Total DDT Levels in Whole Lake Trout (1977-2001). (Canadian data ug/g wet weight +/- S.E., age 4+ - 6+ yrs)
Note the different scales between lakes.
Source: Department of Fisheries and Oceans Canada

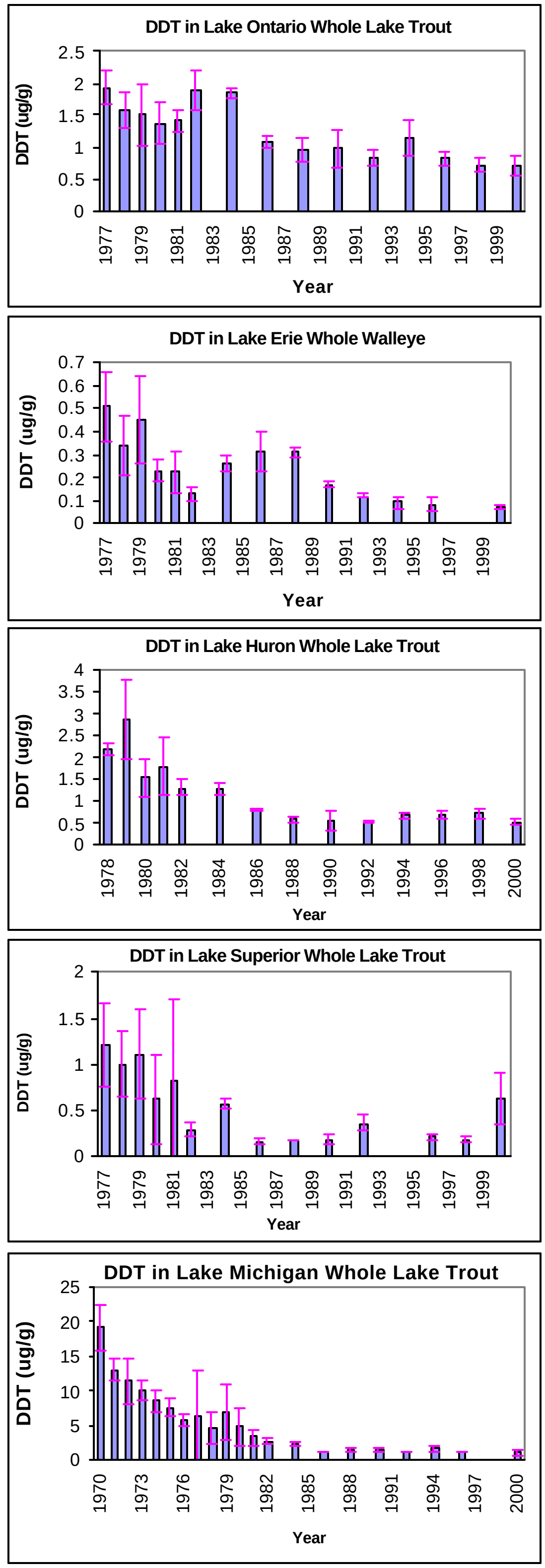
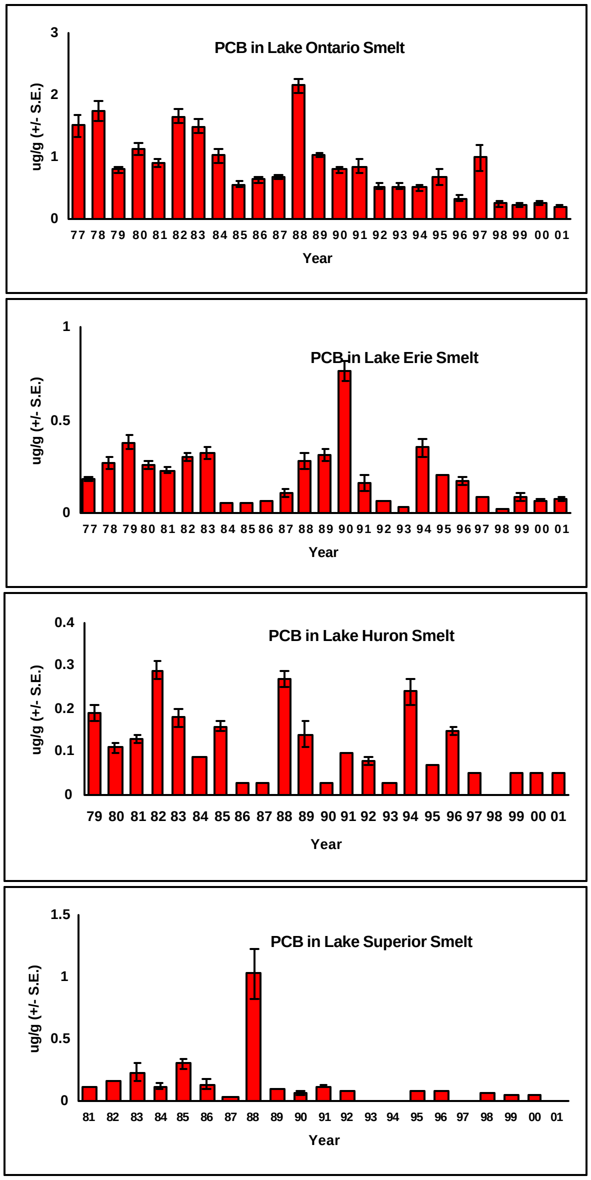



Figure 2a. DDT found in Whole Lake Trout (1977-2001). (ug/g wet weight +/- 95% C.I., composite samples, 600-700 mm size range. Lake Erie data are for walleye in the 400-500 mm size range)
Note the different scales between lakes.
Source: U.S. Environmental Protection Agency



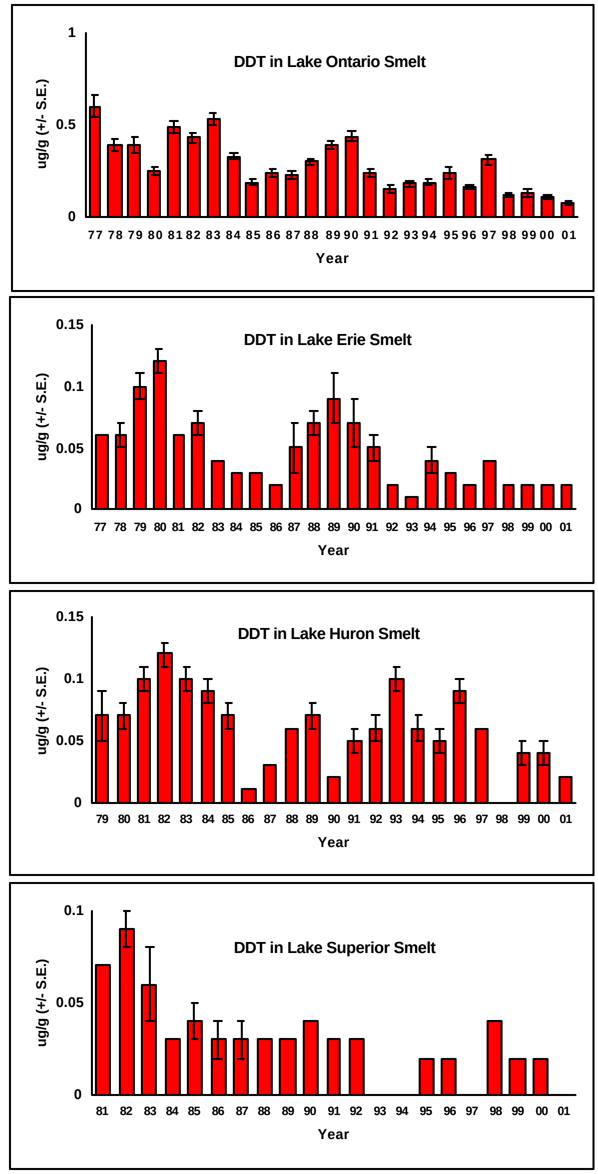




Figure 3. Total PCB Levels in Great Lakes Rainbow Smelt (1977-2001). (Canadian data ug/g wet weight +/- S.E., whole fish)
Note the different scales between lakes.
Source: Department of Fisheries and Oceans Canada

Figure 4. Total DDT Levels in Great Lakes Rainbow Smelt (1977-2001). (Canadian data ug/g wet weight +/- S.E., whole fish)
Note the different scales between lakes.
Source: Department of Fisheries and Oceans Canada

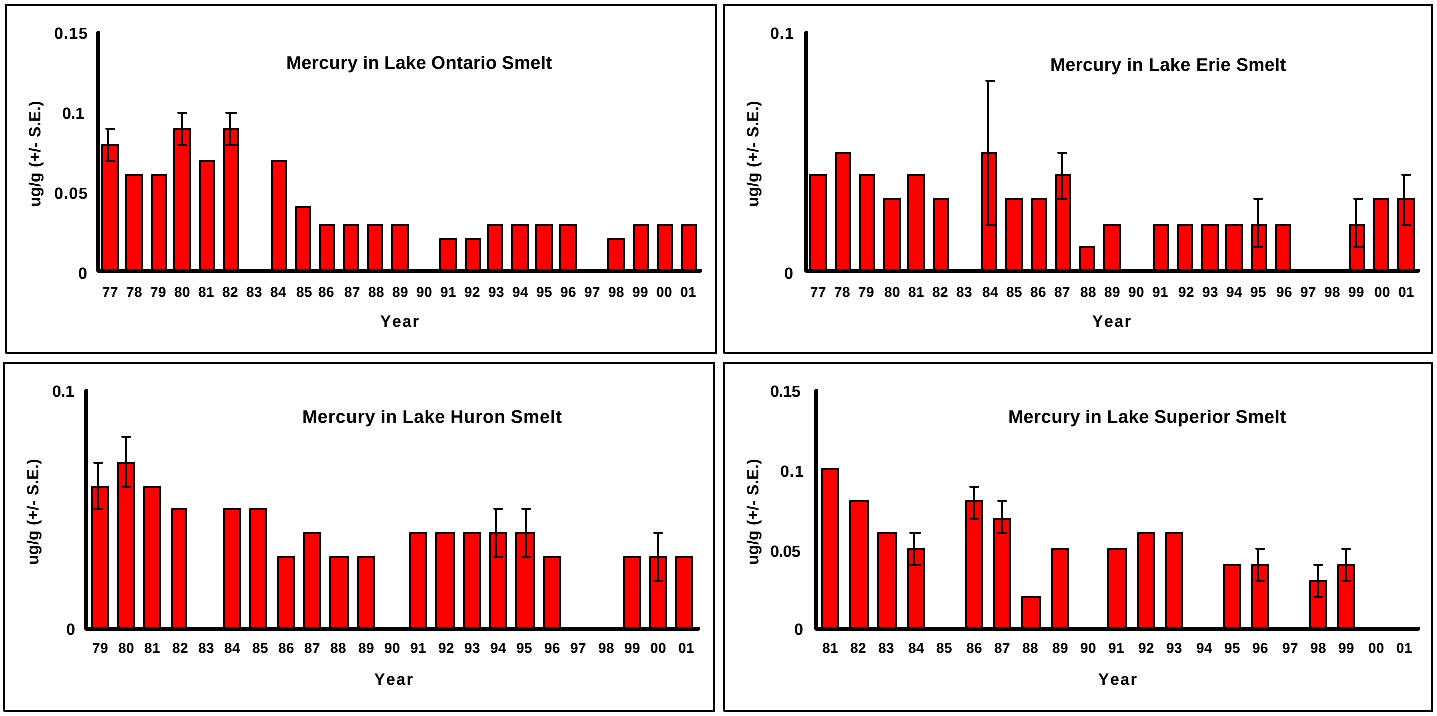



Figure 5. Total Mercury Levels in Great Lakes Rainbow Smelt (1977-2001). (Canadian data ug/g wet weight +/- S.E., whole fish)
Note the different scales between lakes.
Source: Department of Fisheries and Oceans Canada

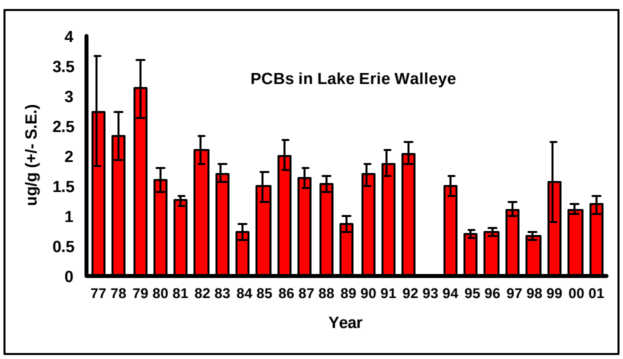



Figure 6. Total PCB Levels in Lake Erie Walleye (1977-2001). (Canadian data ug/g wet weight +/- S.E., ages 4+ - 6+)
Source: Department of Fisheries and Oceans Canada

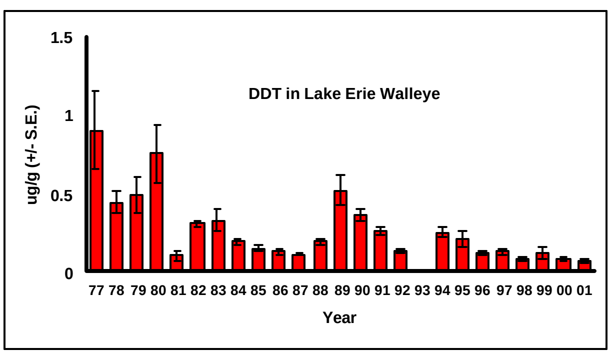



Figure 7. Total DDT Levels in Lake Erie Walleye (1977-2001). (Canadian data ug/g wet weight +/- S.E., ages 4+ - 6+)
Source: Department of Fisheries and Oceans Canada

Most recently polybrominated diphenyl ethers (PBDEs) have been detected in Great Lakes fish at increasing concentrations (Luross, 2002) (Fig. 8). PBDEs are used in brominated flame retardants, which are often applied to textiles. Samples of archived Lake Ontario whole lake trout samples representing the 2-decade time period from 1978 through 1998 were analysed for PBDEs. Levels increased from 3 ng/g lipid in 1978 to a maximum concentration of 945 ng/g lipid weight in 1998. The spatial trend of PBDEs as measured in lake trout across the Great Lakes basin, indicates that while Lake Ontario fish have the highest concentrations (Fig 9), Lake Superior lake trout of the same age class, (6+), have the next highest concentration (DFO - unpublished data).

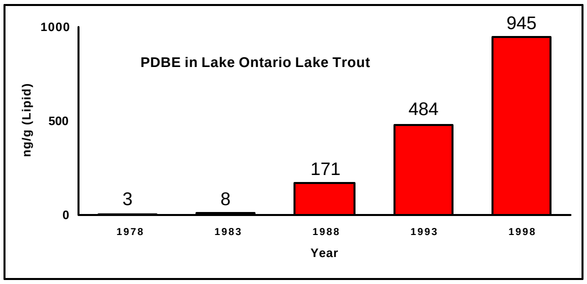



Figure 8. PBDE Trends in Lake Ontario Lake Trout (ng/g lipid weight +/- S.E., whole fish, age 6+ yrs)
Source: Department of Fisheries and Oceans Canada

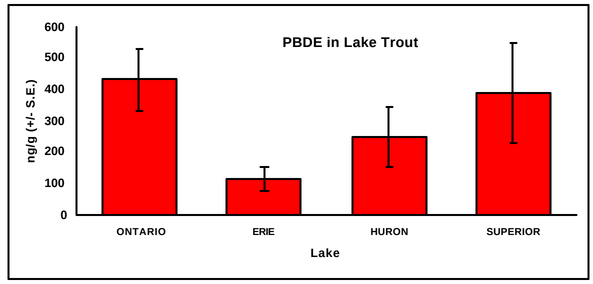



Figure 9. PBDE Levels in Great Lakes Lake Trout (1997) (ng/g per lipid weight +/- S.E., whole fish, age 6+ yrs)
Source: Department of Fisheries and Oceans Canada

### Future Pressures

Probably one of the most immediate pressures impacting on contaminant dynamics in the Great Lakes relates to the increasing proliferation of exotic nuisance species. Their increasing presence has altered both fish community composition and food web energy flows. Thus subsequent changes to pathways and fate of contaminants has resulted in altered bioaccumulation rates in portions of fish communities as evidenced by recent spikes in contaminant burdens. Alterations to the forage base of fish communities have resulted in diet shifts and in some cases, the consumption of a more contaminated prey, which produces elevated body burdens of contaminants. Other pressures relate to the issue of climate change, which includes a warming trend. This change in the thermal regime of the Great Lakes will directly influence the thermodynamics of contaminants and alter bioaccumulation rates. Associated changes in water levels, critical habitat availability and aquatic ecosystem reproductive success will all be future factors influencing contaminant trends in the Great Lakes.

### Further Work Necessary

Future contaminant monitoring studies on the Great Lakes should include more detailed examination of contaminant levels and dynamics in aquatic food webs. These data could be utilized to further develop predictive models to understand the potential changes to contaminant fate and pathways together with alterations in energy flow. If there is a more complete comprehension of possible future scenarios related to changes in environmental conditions and contaminant impacts, there is the potential to develop compensatory management strategies for both remediation of contaminated ecosystems plus the utilization of existing fish stocks for both recreational and commercial harvest.

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DeVault, D.S., R. Hesselberg, P.W. Rodgers and T.J. Feist. 1996. Contaminant Trends in Lake Trout and Walleye From the Laurentian Great Lakes. J. Great Lakes Res. 22(4) 884-895.

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Morrison, H.A., D.M. Whittle, and G.D. Haffner. 2002. A comparison of the transport and fate of PCBs in three Great Lakes food webs. Environ. Toxicol. and Chem. 21:683-692.

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Acknowledgments
D. Mike Whittle, M.J. Keir, and A.A. Carswell, Department of Fisheries & Oceans, Great Lakes Laboratory for Fisheries & Aquatic Sciences, Burlington, ON and Sandra Hellman, USEPA-Great Lakes National Program Office, Chicago, IL.

Status of Lake Sturgeon in the Great Lakes (description)
New Indicator

*Measure*
Population numbers of lake sturgeon in the Great Lakes and their connecting waterways and tributaries.

*Purpose*
Presence of lake sturgeon in abundance in the Great Lakes will indicate a healthy ecosystem. When the Great Lakes were still in pristine conditions (prior to European settlement) lake sturgeon were extremely abundant in the lakes. If the condition of the lakes were improved to the point where lake sturgeon numbers were able to increase, it would indicate a healthy improving ecosystem.

*Ecosystem Objective*
Lake sturgeon are identified by all the Great Lakes in their Fish Community Objectives. Lake Superior has a lake sturgeon management plan, many of the Great Lakes States have lake sturgeon recovery/rehabilitation plans which call for increasing numbers of lake sturgeon beyond current levels. Because lake sturgeon are a native species to the Great Lakes efforts should be put forth to restore their numbers.

*Endpoint*
Lake sturgeon populations increase to the point that they can be removed from state threatened or endangered lists.

*Features of the Indicator*
Efforts are underway to determine the number of active spawning sites for lake sturgeon in the Great Lakes. In addition, work is currently being carried out to genetically determine the status of lake sturgeon in the Great Lakes.

*Illustration*
Graphs for each lake will be displayed depicting the spawning locations and the genetic variability of lake sturgeon collected from that lake.

*Limitations*
This is a relatively costly indicator that requires coordination between federal, state, tribal and provincial agencies. The indicator is linked to the overall health of the Great Lakes ecosystem.

*Interpretation*
Variations in spawning periodicity of lake sturgeon and the effect that river flow rates have on spawning could affect annual results and complicate interpretation of long-term trends.

*Comments*
Increasing passage for lake sturgeon at hydroelectric facilities is needed to allow fish access to historic spawning sites. In addition to this, creation of artificial spawning sites might aid the recovery process.

*Unfinished Business*
More information is needed on the current status of lake sturgeon populations. Standardized protocols and continued sampling of existing populations. The largest source of unknown

information is related to juvenile lake sturgeon (age 0-2). Considerable research needs to be conducted to determine the habitat preferences and location of this age group of lake sturgeon.

*Relevancies*
Indicator Type:
Environmental Compartment(s):
Related Issue(s):
SOLEC Grouping(s):
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

*Last Revised*
July 16, 2002

## Status of Lake Sturgeon in the Great Lakes (sample report)

New Indicator

### Purpose

Historically, lake sturgeon were abundant in the Great Lakes and the waterways that connect them (St. Mary's, St. Clair, Detroit and St. Lawrence Rivers). Although once extremely abundant these huge fish suffered serious population declines in the late 1800s due to a combination of overexploitation and habitat degradation. Lake sturgeon numbers declined to levels requiring state listing as threatened or endangered in 19 or 20 states in their original range (Wisconsin is the one exception). Lake sturgeon are benthic feeding fish that hold a low, but essential, position in the trophic food web of the Great Lakes. Lake sturgeon are an important native species that are listed in the fish community objectives for all Great Lakes. Many of the Great Lakes states and provinces are developing lake sturgeon management plans calling for the need to inventory, protect and restore the species to greater levels of abundance.

### Ecosystem Objective

While overexploitation removed millions of adult fish, habitat degradation and alteration eliminated traditional spawning grounds. Currently work is underway by state, federal, tribal, provincial and private groups to document active spawning sites and determine the genetics of remnant Great Lakes lake sturgeon populations.

### State of the Ecosystem

Lake sturgeon populations are known to be abundant in the connecting waterways of the Great Lakes. Efforts are underway by many groups to gather information on remnant spawning population in the Great Lakes. Unfortunately, much information is lacking on the current status of lake sturgeon in the Great Lakes. Essentially no information exists on juvenile lake sturgeon (ages 0-2). This is the largest knowledge gap and possible the biggest impediment to rehabilitating lake sturgeon population in the Great Lakes.

### Future Pressures

Barriers that prevent lake sturgeon from moving into tributaries to spawn are a major problem. Predation on eggs and newly hatched lake sturgeon by non-native predators may also be a problem. Lack of knowledge of the genetics of current populations needs to be addressed. With the collapse of the Caspian Sea sturgeon populations black market demand for sturgeon caviar could put tremendous pressure on Great Lakes lake sturgeon populations.

### Future Activities

Work is underway to develop a spiral-stairway passage device that would pass lake sturgeon around dams. Work is also being conducted to gather genetic information on lake sturgeon stocks in the Great Lakes. Many groups are working to identify current lake sturgeon spawning locations in the Great Lakes. Studies are also being initiated to identify habitat preferences for juvenile lake sturgeon (ages 0-2).

### Further Work Necessary

More information is needed to determine ways to get lake sturgeon past barriers on rivers. More monitoring is needed to determine the current status of Great Lakes lake sturgeon populations. More information is also needed on juvenile lake sturgeon. More law enforcement is needed to protect large adult lake sturgeon.

Sources
Auer, Nancy. Lake Sturgeon: A Unique and Imperiled Species in the Great Lakes. Chapter 17 in Great Lakes Fisheries Policy and Management: A Binational Perspective.

Acknowledgments
Author: Tracy D. Hill, U.S. Fish and Wildlife Service, Alpena FRO, Alpena, MI.

Climate Change: Effect on Crop Heat Units
New Indicator

*Measure*
The temporal change in seasonal Crop Heat Units (CHU) in the Great Lakes basin. Crop Heat Units are indicators of crop suitability, used to assist farmers in selecting the most appropriate varieties or hybrids of crops specifically corn and soybeans suitable for their area. They represent the total accumulated CHU for the frost-free growing seasons in each area.

*Purpose*
To assess the trends in Crop Heat Units in the Great Lakes basin as an indicator of climate change. A change in atmospheric temperature due to climate change has the potential to increase Crop Heat Units. This indicator may also aid to infer the potential impact climate change has on species diversity and crop productivity.

*Ecosystem Objective*
GLWQA General Objective: "These waters should be free from materials and heat directly or indirectly entering the waters 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 CHU in the Great Lakes basin. Changes in Crop Heat Units will affect the spatial variability, species diversity and productivity of crops in the Great Lakes basin.

*Endpoint*
An endpoint will need to be established, based on a literature search of historical data, to determine the average Crop Heat Units in the Great Lakes basin prior to when the effects of climate change are evident.

*Features*
Crop Heat Units are essentially crop development units, they are used to predict how climate, affects the growth and development of crops from planting to maturity. Temperature is the most important among all environmental factors that influence rate of plant development.

Daily temperatures are influenced by latitude, elevation and location (such as the proximity to large water bodies). Lower overall temperatures tend to impede crop growth where as warmer temperatures support crop growth. It is predicted that increases in temperature and subsequent increases in CHU due to climate change will eliminate many natural habitats and change their potential productivity making them more suitable to human economic activities such as farming. It is predicted that climate change will produce a positive change in agricultural productivity such as increased yields in corn and soybeans in the Upper Great Lakes region.

According to Rochefort and Woodward (1992), climate is often hypothesized to be the primary factor in determining species composition and defining plant distribution. It is predicted that a 3°C increase in temperature as determined from General Circulation Models (GCM's) will increase the diversity of approximately one third of the worlds floristic regions. Bootsma (2002), also predicts using Canadian General Circulation Model (CGM1) scenarios that CHU in Ontario, near the Great Lakes would increase by over 400 for the period 2010 – 2039 and between 800 for the period 2049 – 2069. It is also predicted that areas on the US side of the basin that presently have CHU ~2800 will display increases in crop yield of up to 2025. For grain corn and soybeans, the earliest available hybrids/varieties require ~ 2300 CHU.

These GCM also predict that the mean surface temperature will warm by 3°C, and the global mean precipitation will increase by 10%. However, it must be noted that GCM's are essentially mathematical formulations of atmosphere, ocean and land surface processes, they do not include vegetation. According to Rochefort and Woodward (1992), the exclusion of vegetation leads to significant errors in surface energy balance and hydrological calculations.

*Illustration*
A graph showing the Seasonal Crop Heat Units for different regions in the Great Lakes basin on the y-axis and years on the x-axis, beginning with the cutoff date for the historical data. The graph will indicate the overall trend and also will display extreme events. Time series maps showing the contours of CHU in the Great Lakes basin and how these contours have migrated or changed would also provide useful information.

*Limitations*
A limitation of the CHU method is that it assumes temperature will have the same response on a crop regardless of its developmental stage. However, corn responds more sensitively to temperature in the vegetative to silking stage as opposed to the stage from silking to maturity.

In addition, CHU assumes that plant growth is directly related to temperature only, however other environmental factors such as photoperiod (the daily period from sunrise to sunset), soil fertility, soil moisture, slope and location also affect plant growth.

*Interpretations*
Information on changes in species diversity and crop yield from vegetation surveys and harvest data collected over time in the Great Lakes basin will help to strengthen the link between CHU, species diversity and productivity. It also should be noted that past and future changes in species diversity and crop yields may be attributed to development of higher yielding hybrids and to changes in input costs of production.

Increased temperature and subsequent increases in CHU could expand areas where corn and soybeans can be economically produced, allowing longer season hybrids to be grown provided that increased temperature does not lead to increased water deficits. Thus producers in the Great Lakes basin will likely shift to corn and soybeans as the climate warms.

*Comments*
To interpret this indicator, climatological data including daily maximum and minimum temperature will need to be collected. Separate calculations need to be conducted for both day and night, as the daily CHU is the average of the two. According to Brown and Bootsma (1993), the daytime relationship uses 10°C (50°F) as a base temperature and 30°C (86°F) as an optimum, because warm season crops do not develop when daytime temperatures fall below 10°C and they develop fastest at 30°C. The nighttime relationship uses 4.4°C (40°F) as the base temperature and does not specify an optimum temperature because nighttime minimum temperature seldom exceeds 25°C in Ontario. The seasonal CHU are obtained by adding all the daily CHU values between the start and the end date.

$$CHU_{day} = 3.33\ (T_{max} - 10.0°C)) - 0.084\ (T_{max} - 10.0°C)^2$$
$$CHU_{night} = 9/5\ (T_{min} - 4.4°C)$$
$$CHU = (CHU_{day} + CHU_{night})/2$$

When doing calculations the start and end date of the daily accumulations need to be determined to get annual sums. According to Brown and Bootsma (1993) the date to start accumulating CHU is estimated as: 1) The last day of 3 consecutive days with daily mean air temperature less than 12.8°C (55°F) and 2) The starting date for this 3-day period each year occurred after the date the 30 year average daily mean temperature reached 10°C (50°F) in spring for each weather station site. The end date which CHU stop accumulating is either 1) the first occurrence of –2°C (28°F) or 2) the date when the 30 year daily mean air temperature dropped to 12°C or lower.

Climatological data is easily accessible from meteorological stations in Canada from Environment Canada's, Meteorological Service of Canada and in the U.S. from the National Climatic Data Center.

CHU is recognized around the U.S. and Canada as one of the best methods to quantify the effect of temperature on corn development.

*Unfinished Business*

*Relevancies*
Indicator Type: pressure
Environmental Compartment(s): biota
Related issue(s): climate change, species diversity
SOLEC Grouping(s): unbounded
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

*Last Revised*
August 9, 2002

Climate Change: Number of Extreme Storms
Indicator ID: #4519 (revised to add definition of Extreme Storm)

*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, using the defined parameters of central pressure, maximum wind gusts, and total precipitation.

*Purpose*
To assess the number of "extreme storms" each year, and to infer the potential impact on ecological components of the Great Lakes of increased numbers of severe storms due to climate change.

"*Extreme Storm*": Any storm occurring during ice-free and ice-breakup periods, which meets two of the following three criteria:

- a central atmospheric pressure less than 990mb
- the recorded maximum wind gusts in a 24hr period, with wind speeds greater than 48 knots
- total precipitation over the storms duration with amounts of 75 mm for summer and 25 mm for winter

*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.

*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.

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.

Aside from these general assumptions there are other limitations which may directly impair the results of this indicator:

1) The number of storms that occur would have to be separated based on which season they develop.

2) Sufficient historical records are not easily obtained. Most basin wide reports only date back a few years, not long enough to develop any trends in the output.

3) With different individuals working on this project, the ability to successfully transfer data from one person to the next becomes difficult.

4) The defined parameters are subjective when describing when the spatial distribution of a storm system, i.e. does a continually regenerating storm cell from the same system get counted multiple times. This leads into the concept of storm duration. What if a storm fits two of the parameters in one region, falls out of the limits as it moves out of the region, but then re-surges at a later date? Will it be considered two separate storms.

5) Will marine based storms still be counted as "Extreme" if they fit the definition but don't strike land?

*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.

As stated above the concept of "Extreme Storms" is very subjective. Many storms that occur do not fit the definition of extreme, however they are still considered extreme by public standards. As an example, if the definition were applied to the ice storm of 1997, it would not have met the specified parameters. Yet this storm was still considered extreme.

Due to the number of limitations on this indicator, another route has been suggested, one that can be directly linked to almost all of the other climate indicators: heat unit observations.

*Unfinished Business*

*Relevancies*
Indicator Type: pressure
Environmental Compartment(s): air
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):

*Last Revised*
April 8, 2002

# 9. Proposed Changes to Indicators in the Current Great Lakes Suite of Indicators

Two indicators in the current Great Lakes suite are combined indicators - that is they have combined two different measures into one indicator. These are Walleye and *Hexagenia* (#9) and Lake Trout and Scud (*Diporeia*) (#93). Even though they were developed to determine the state of warm-cool water ecosystems and cold water ecosystems respectively, they are each reported separately. It was felt that the descriptions should also be separated - however the Walleye description is unavailable at this time.

The indicator DELT (Deformities, Erosed Fins, Lesions and Tumors) in Nearshore Fish is proposed to be changed to an index of external anomalies called External Anomaly Prevalence Index (EAPI) in Nearshore Fish.

All of these indicators have had an indicator report prepared. The Walleye, *Hexagenia*, Lake Trout and *Diporeia* indicator reports can be found in the *Implementing Indicators* draft report, while the EAPI indicator report follows the indicator description in this paper.

Walleye (description)
Indicator ID: #9

Revised description coming soon...

*Hexagenia*
Indicator ID: #9a (revised description)

*Measure*
Abundance, biomass, or annual production of burrowing mayfly (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-early July in areas of historical abundance.

*Purpose*
This indicator will show the status and trends in *Hexagenia* populations, and will be used to infer the health of the *Hexagenia* populations and the Great Lakes ecosystem.

*Ecosystem Objective*
Historical mesotrophic habitats should be maintained as balanced, stable, and productive elements of the Great Lakes ecosystem with *Hexagenia* as the key benthic invertebrate organism in the food chain. (Paraphrased from Final Report of the Ecosystem Objectives Subcommittee, 1990, to the IJC Great Lakes Science Advisory Board.) In addition, this indicator supports Annex 2 of the GLWQA.

*Endpoint*
Appropriate quantitative measures of abundance, biomass, or production should be established as reference values for self-sustaining populations of *Hexagenia* in mesotrophic habitats in each lake.

*Features*
The historical dominance of *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 of *Hexagenia* throughout their native range in the basin will help ensure their dominance 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 *Hexagenia* populations. 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*
*Hexagenia* are extirpated at moderate levels of pollution, and more research is needed to develop data needed to show a graded response to pollution. Target reference values for the indicator are being 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 OMOE 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 by *Hexagenia*, if surficial sediments are otherwise uncontaminated.

Unfinished Business
- 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 *Hexagenia* populations over time?

*Relevancies*
Indicator Type: state
Environmental Compartment(s): biota, fish
Related Issue(s): contaminants & pathogens, 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
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 6: Degradation of benthos

*Last Revised*
March 7, 2000

Lake Trout
Indicator ID: #93 (revised description)

*Measure*
Absolute abundance, relative abundance, yield, or biomass, and self-sustainability through natural reproduction of lake trout in coldwater habitats of the Great Lakes.

*Purpose*
To show the status and trends in lake trout populations, a major coldwater predator and subject of an international effort to rehabilitate populations to near historic levels of abundance.

*Ecosystem Objective*
The coldwater regions of the Great Lakes should be maintained as a balanced, stable, and productive ecosystem with self-sustaining lake trout populations as a major top predator.

*Endpoint*
Self-sustaining, naturally reproducing populations that support target yields to fisheries is the goal of the lake trout rehabilitation as established by the Fish Community Objectives drafted by the Great Lakes Fishery Commission. Target yields approximate historical levels of lake trout harvest or adjusted to accommodate stocked exotic predators such as Pacific salmon. These targets are 4 million pounds from Lake Superior, 2.5 million pounds from Lake Michigan, 2.0 million pounds from Lake Huron and 0.1 million pounds from Lake Erie. Lake Ontario has no specific yield objective but has a population objective of 0.5-1.0 million adult fish that produce 100,000 yearling recruits annually through natural reproduction. The lake trout is a highly valued species that is 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 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 metrics including natural reproduction 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. Because the indicator includes only a single species, it may not reliably diagnose ecosystem health. Also, because lake trout abundance can be easily reduced by overfishing and sea lamprey

predation, harvest restrictions designed to promote sustained use and enhanced sea lamprey control are required if the species is to be used as an indicator of ecosystem health. Annual interagency stock assessments measure changes in relative abundance, size and age structure, survival, and extent of natural reproduction but do not provide direct feedback to yield goals.

*Interpretation*
Interpretation is direct and simple. If natural reproduction is observed and contributing significantly to the target values, the system can be assumed to be healthy; if the values are not met then causative agents of impairment are implicated and need to be addressed.

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

*Last Revised*
August 2002

Benthic Amphipod (*Diporeia* spp.)
Indicator ID: #93a (revised description)

*Measure*
Abundance or biomass, and self-sustainability of *Diporeia spp*. in cold, deepwater habitats of the Great Lakes.

*Purpose*
To show the status and trends in *Diporeia* populations, and to infer the basic structure of coldwater benthic communities and the general health of the ecosystem.

*Ecosystem Objective*
The cold, deepwater regions of the Great Lakes should be maintained as a balanced, stable, and productive oligotrophic ecosystem with *Diporeia* as one of the key organisms in the food chain. Relates to Annex 1 of the GLWQA.

*Endpoint*
In Lake Superior, *Diporeia* should be maintained throughout the lake at abundances of $>200/m^2$ at depths <100m and $>30/m^2$ at depths >100m. In the open waters of the other lakes, *Diporeia* should be maintained at abundances of $> 1{,}000/m^2$ at depths 30-100m and $>200/m^2$ at depths > 100m. These are conservative density estimates for these depths. Density estimates at depths < 30 m in all the lakes can be highly variable and subject to local conditions. Thus, densities at these shallower depths may not be a good indicator of lake-wide trends.

*Features*
*Diporeia* abundances are measured in assessment programs carried out annually in each lake. Other, more regional assessments occur less frequently. The historical dominance of *Diporeia* in cold, deepwater habitats in all of the Great Lakes provides a good basis for a basin-wide evaluation of ecosystem health.

*Illustration*
For each lake, a figure with *Diporeia* metrics on the y-axis and year on the x-axis will be presented. For less frequent but more spatially-intense regional assessments, a figure giving metric contours or isopleths will be presented.

*Limitations*
The indicator is of greatest value in assessing ecosystem health in the cold, open-water portions of the Great Lakes. It may also be useful when assessing long term trends within a specific lake region in the nearshore (< 30 m), but its value is questionable if widely applied to nearshore areas over all the lakes. Because this indicator consists of only one taxa, it may not reliably diagnose causes of degraded ecosystem health. A number of lakewide surveys and assessments of benthic invertebrate communities have been made over the past several decades in the Great Lakes and the current status of *Diporeia* populations is generally known, and an understanding of *the* changes related to the Dreissenid mussel invasion is emerging.

*Interpretation*
Target values are provided to evaluate abundances on a historic basis. Trends over time provide a means to assess indicator direction. On a more direct basis, if 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*

*Diporeia* is the dominant benthic macroinvertebrate in the cold, deepwater habitats of all the Great Lakes, comprising over 70% of benthic biomass in these regions. It feeds on material settled from the water column and, in turn, is fed upon by many species of fish. As such, it plays a key role in the food web of deepwater habitats. Among the fish species that are energetically linked to *Diporeia* is the lake trout. Young lake trout feed on *Diporeia* directly, while adult lake trout feed on sculpin, and sculpin feed heavily on *Diporeia*. Lake trout are a top predator in the deepwater habitat and abundances are another SOLEC Indicator. Therefore assessments of both *Diporeia* and lake trout provide an evaluation of lower and upper trophic levels in the cold, deepwater habitat.

*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

*Last Revised*

October 20, 1999

External Anomaly Prevalence Index (EAPI) for Nearshore Fish
Indicator ID: #101 (revised description)

*Measure*
An index of external anomalies in nearshore fish that will include the prevalence of external raised lesions and the prevalence of barbel abnormalities for brown bullhead.

*Purpose*
This indicator will assess the combination of external anomalies in nearshore fish that will be used as an estimate of ecosystem health within the Great Lakes.

*Ecosystem Objective*
To restore and protect beneficial uses in Areas of Concern or in open lake waters, including beneficial use (iv) *Fish tumors or other deformities* (GLWQA, Annex 2). This indicator also supports Annex 12 of the GLWQA

*Endpoint*
When the incidence rate of external anomalies does not exceed rates at unimpacted reference sites (IJC Delisting criteria, see IJC 1996)

*Features*
Epizootics outbreaks or elevated frequencies of internal tumors (neoplasms, including cancer) have become more frequent in the past three decades. The neoplasms 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.

While some tumors are genetically induced and others are virally induced, there is a substantial body of evidence from field and laboratory studies showing that chemical carcinogens cause neoplasia of the types seen in Great Lakes fishes.

Recent research demonstrates that external anomalies might also be useful in assessing beneficial use impairment. The External Anomaly Prevalence index (EAPI) provides useful method of quantitatively comparing external anomalies. Historically, a decline in PAHs in river sediment in a Great Lakes tributary was accompanied with a decline in liver tumors in brown bullhead. Evidence also shows that external anomaly prevalence in fish from Great Lakes tributaries is positively associated with both chemical contaminants in sediment and with genetic damage.

Restoration of Great Lakes aquatic habitats polluted with chemical carcinogens is now underway. The success of this restoration may be best demonstrated by using the EAP index for nearshore fish such as brown bullhead or white suckers. This indicator is similar to 4503, but applied to nearshore fish species rather than to coastal wetland species.

*Illustration*
For selected Areas of Concern, a graph will be presented showing the EAPI in brown bullhead over time.

*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 relation of contaminated harbor sediments and external anomalies and their usefulness as indicators of ecosystem health.

*Interpretation*
Internal tumors are generally believed to be a response to a degraded habitat and toxic exposure to carcinogens, but may also be due to immune suppression and exposure to viral agents. Prevalence of internal tumors should be cross-correlated with location to determine trends. Impairment determinations will be based on a comparison of rates of occurrence of internal tumors or related external anomalies at sites of interest with rates at unimpacted or least-impacted (reference) sites. Impairment is defined by:

1. An internal tumor prevalence of >5% occurs in mature native near-shore species of benthic fishes ( e.g., brown bullhead, black bullhead, white sucker, and several species of redhorse). Tumors are histopathologically verified neoplasms of intestinal, bile duct, or liver cells only.

2. A prevalence of raised growth on lips >10%, or of overall external raised growth on body and lips >15% in any of the mature benthic species listed in 1 above.

3. A prevalence of barbel abnormalities (missing or deformed barbels) of >20% occurs in mature brown or black bullhead.

*Comments*
This indicator was prepared using information from:
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*
Canadian and US investigators need to combine available pathology data on Great Lakes near-shore benthic species into a single data base. A collaborative study using standardized methodology over a series of locations representing a contamination gradient would further allow the index to be fine tuned and correlated with other aspects of environmental health at Great Lakes Areas of Concern.

*Relevancies*
Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
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): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances GLFC Objective(s): Beneficial Use Impairment(s): 4: Fish tumors and other deformities

*Last Revised*
August 5, 2002

External Anomaly Prevalence Index (EAPI) for Nearshore Fish (sample report)
Indicator ID: #101 (revised)

*Purpose*
This indicator will assess external anomalies in nearshore fish. An index will be used to identify areas where fish are exposed to contaminated sediments within the Great Lakes. The presence of contaminated sediments at Areas of Concern (AOCs) has been correlated with an increase incidence of anomalies in benthic fish species (brown bullhead and white suckers), that may be associated with specific groups of chemicals.

*Ecosystem Objective*
As a result of clean-up efforts, AOCs that historically have had a high incidence of fish with external anomalies currently show fewer abnormalities. Use of an External Anomaly Prevalence Index (EAPI) based on prevalent external anomalies will help identify nearshore areas that have populations of benthic fish exposed to contaminated sediments and will help assess the recovery of AOCs following remedial activities. The objective is to help restoration and protection of beneficial uses in Areas of Concern or in open Great Lakes waters, including beneficial use (iv) *Fish tumors or other deformities* (GLWQA, Annex 2). This indicator also supports Annex 12 of the GLWQA.

*State of the Ecosystem*
Elevated incidence of liver tumors (histopathologically verified pre-neoplastic or neoplastic growths) were frequently identified during the past two decades. These elevated frequencies of liver tumors have been shown to be useful indicators of beneficial use impairment of Great Lakes aquatic habitat. External raised growths (sometimes as histopatholigically verified tumors on the body and lips), such as papillomas have been a useful indicator. Raised growths may not have a single etiology; however, they have been produced experimentally by direct application of PAH carcinogens to brown bullhead skin. Field and laboratory studies have correlated chemical contaminants found in sediments at some AOCs in Lake Erie, Michigan, Ontario and Huron with verified liver and external raised growths. Other external anomalies may also be used to assess beneficial use impairment; however, they must be carefully evaluated. The external anomaly prevalence index (EAPI) will provide a tool for following trends in fish population health that can be used by resource managers and community-based monitoring programs.

EAP Index — The external anomaly prevalence index (EAPI) is being developed for mature (> 3 years of age) fish as a marker of both contaminant exposure and of internal pathology. Brown bullhead has been used to develop the index. They are the most frequently used benthic indicator species in the southern Great Lakes and are been recommended by the International Joint Commission (IJC) as the key indicator species (IJC 1989). The most common external anomalies found in brown bullhead over the last twenty years from Lake Erie (Figure 1) are:

1) Abnormal barbels (BA);
2) Focal discoloration (FD);
3) Raised growths (RG) - on the body and/or lips (L); and
4) Eye Abnormality (EYE)– blind in one or both eyes.

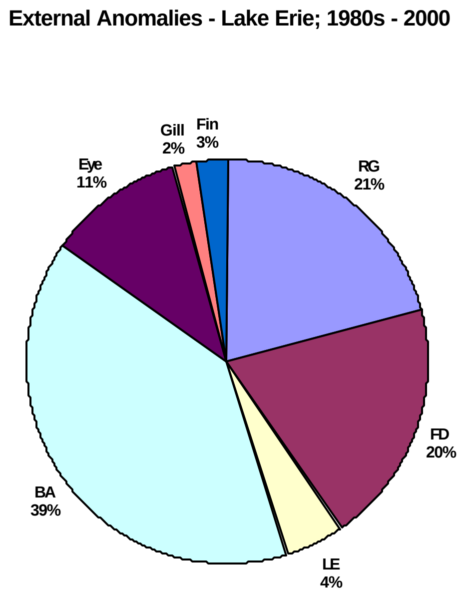


**Figure 1.** External Anomalies on brown bullhead collected from Lake Erie from 1980s through 2000. BA – barbel abnormality, RG– raised growth (body and lip), FD-focal discoloration, LE – lesion (total 4439 fish).

Initial statistical analysis of sediments and external anomalies at different locations indicates that alterations in the ratio of the chemical mixtures (PAH, PCB, OC, metals) are reflected in an alteration of the comparative prevalence of individual external anomalies. Impairment determinations should be based on comparing the prevalence of external anomalies at potentially contaminated sites with the prevalence at "reference" (least impacted) sites. Preliminary data indicates that the prevalence of lip raised growths (lip papillomas) is >10%, or of overall external raised growth (body and Lip) >15% in brown bullhead, that the population should be considered impaired. The additional use of barbel abnormalities and focal discoloration (melanistic alterations) will help to differentiate degrees of impairment of fish population health. Figure 2 illustrates the comparison of AOCs with contaminated sediments to reference conditions at HUR (Huron River) and OWC (Old Woman Creek).

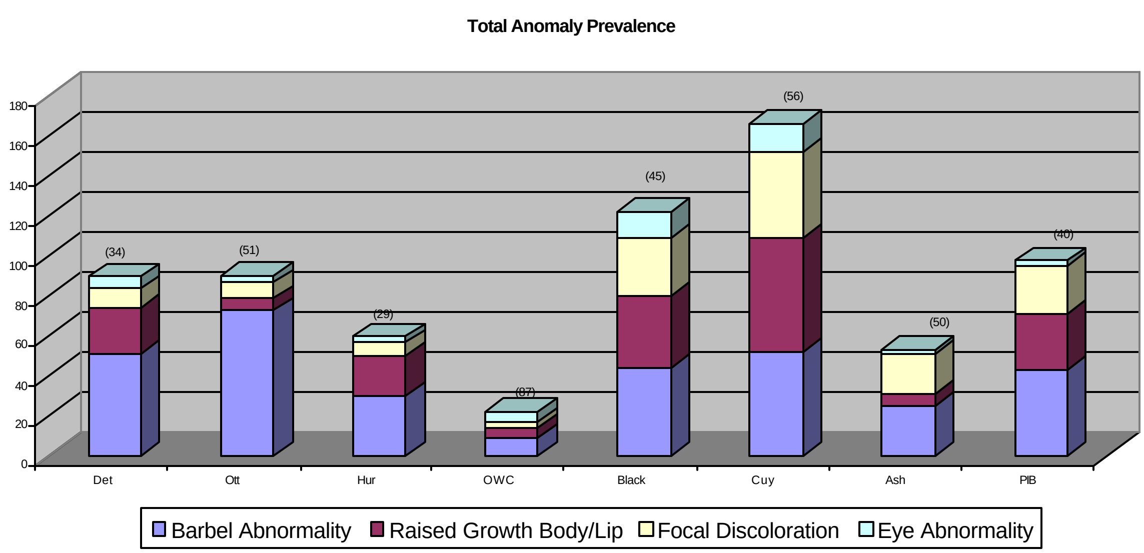


**Figure 2.** Prevalence of four most common external anomalies at Lake Erie AOCs. [Det - Detroit River, MI; OTT - Ottawa River, OH; Hur - Huron River, OH (Reference); OWC - Old Woman's Creek, OH (Reference); Black River, OH; Cuy - Cuyahoga River, OH – Cleveland Harbor and upstream combined; Ash - Ashtabula River, OH; PIB - Presque Isle Bay, PA]

*Future Pressures*

As the Great Lakes AOCs and the tributaries continue to remain in a degraded condition, exposure of the fish populations to contaminated sediments will continue to cause elevated incidence of external anomalies. Population expansion and industrialization of Great Lakes tributaries and shorelines will certainly increase even as control measures and remediation of old contaminated sites are implemented. Fish populations at many of these sites may continue to be exposed to contaminants capable of causing external anomalies.

*Future Activities*

Additional remediation to clean-up contaminated sediments will help to reduce rates of external anomalies. The EAPI, particularly for brown bullheads and white suckers, will help follow trends in fish population health and will help determine the status of AOCs that may be considered for delisting (IJC Delisting Criteria, see IJC 1996).

*Future Work Necessary*

This external anomaly indicator for benthic species has potential for defining habitats that are contaminated. Collaborative U.S.-Canadian studies investigating the etiology and prevalence of external anomalies in benthic fishes over a gradient of polluted to pristine Great Lakes habitats are needed. These studies would create a common index that could be used as an indicator of ecosystem health.

*Sources*

International Joint Commission. 1989. Guidance on characterization of toxic substances problems in areas of concern in the Great Lakes Basin. Report of the Great Lakes Water Quality Board. Windsor, ON, Canada.

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

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