Implementing Indicators 2003

A Technical Report

Environment Canada
and
United States Environmental Protection Agency

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Implementing Indicators 2003 A Technical Report

by the Governments of
Canada
and
the United States of America

Prepared by
Environment Canada
and the
U.S. Environmental Protection Agency

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Preface

The governments of Canada and the United States are committed to providing public access to environmental information that is reported through the State of the Lakes Ecosystem Conference (SOLEC). This commitment is integral to our mission to protect the environment and human health. To participate effectively in managing human health and environmental risks, all Great Lakes stakeholders (e.g., federal, provincial, state and local governments) as well as First Nations and Tribes; non-governmental organizations; industry; academia; private citizens, should have access to accurate information of appropriate quality and detail.

Implementing Indicators 2003-A Technical Report is the complete compilation of the indicator reports developed from the Implementing Indicators paper, circulated for review at SOLEC 2002. This technical report provides fully referenced documentation for the information presented in each indicator report. The purpose of these indicator reports is to outline the status of specific parameters within the basin in order to gauge the relative health of the Great Lakes ecosystem. Some of these reports are updated annually while other reports have a less frequent cycle of review. This reporting timeframe is based upon the nature of the indicator, research and monitoring initiatives, and the rate of change in the specific indicator parameters within the Great Lakes basin. The data presented in some cases is representative of the entire basin, while other indictors highlight only certain geographic locations.

Summaries of these indicator reports have been included in the State of the Great Lakes 2003 report. Also included in this standard report is a status report on each of the Great Lakes and connecting channels. These summaries were primarily based on presentations made at SOLEC 2002 in Cleveland, Ohio. These presentations along with the associated speaking notes can be viewed online at:

www.epa.gov/glnpo

To receive a copy of the State of the Great Lakes 2003 report please contact:

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http://www.binational.net/

This approach of dual reports, one relatively easy to read (*State of the Great Lakes 2003* report) and one with details and references to data sources (*Implementing Indicators 2003 - A Technical Report*), also satisfies *Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal* Agencies, OMB, 2002, (67 FR 8452). The guidelines were developed in response to U.S. Public Law 106-554; H.R. 5658, Section 515(a) of the Treasury and General Government Appropriations Act for Fiscal Year 2001.

The development and maintenance of the Great Lakes suite of indicators is an evolving process. Efforts are underway to further refine this suite to ensure that the indicator information is accessible and to ensure that the information being presented can be used to effectively assess the health and state of the Great Lakes ecosystem.

Section 1
Indicator Assessments

1.1 STATE INDICATOR REPORTS-PART 1

SUMMARY OF STATE INDICATORS-PART 1

The overall assessment for the State indicators is incomplete. Part One of this Assessment presents the indicators for which we have the most comprehensive and current basin-wide information. Data presented in Part Two of this report represent indicators for which information is not available year to year or are not basin-wide across jurisdictions. Within the Great Lakes indicator suite, 38 have yet to be reported, or require further development. In a few cases, indicator reports have been included that were prepared for SOLEC 2000, but that were not updated for SOLEC 2002. The information about those indicators is believed to be still valid, and therefore appropriate to be considered in the assessment of the Great Lakes. In other cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

Indicator Name	Assessment in 2000	Assessment in 2002
Salmon and Trout	No Report	Mixed
Walleye	Good	Mixed
Hexagenia	Mixed, improving	Mixed, improving
Preyfish Populations	Mixed	Mixed, deteriorating
Lake Trout	Mixed	Mixed
Abundance of Benthic Amphipod *Diporeia*	Mixed	Mixed, deteriorating
Benthic Diversity and Abundance	No Report	Mixed
Phytoplankton Populations	Not Assessed	Mixed
Zooplankton Populations	Not Assessed	Mixed
Amphibian Diversity and Abundance	Mixed, deteriorating	Mixed, deteriorating
Wetland-Dependent Bird Diversity and Abundance	Mixed, deteriorating	Mixed, deteriorating
Area, Quality and Protection of Alvar Communities	Mixed	Mixed

Green represents an improvement of the indicator assessment from 2000.
Red represents deterioration of the indicator assessment from 2000.
Black represents no change in the indicator assessment from 2000, or where no previous assessment exists.

Salmon and Trout

Indicator ID #8 - Indicator Matrix

Assessment: Mixed

Purpose
This indicator shows trends in populations of introduced trout and salmon species in the Great Lakes basin. These trends have been used to evaluate the resulting impact on native fish populations.

Ecosystem Objective
In order to manage Great Lakes fisheries, a common fish community goal was developed for all management agencies; "To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, cultural heritage, employment and income, and a healthy aquatic ecosystem" (GLFC, 1997).

Each lake has individual Fish Community Goals and Objectives (FCGO) for introduced trout and salmon species, in order to establish harvest or yield targets consistent with FCGO for lake trout restoration, and in Lake Ontario, for Atlantic salmon restoration.

Lake Ontario (1999): Salmon and trout catch rates in recreational fisheries continuing at early-1990s levels.
Lake Erie (1999 draft): Manage the eastern basin to provide sustainable harvests of valued fish species, including…lake trout, rainbow trout and other salmonines.
Lake Huron (1995): A diverse salmonine community that can sustain an annual harvest of 2.4 million kg with lake trout the dominant species and anadromous (stream-spawning) species also having a prominent place.
Lake Michigan: A diverse salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg (6 to 15 million lb), of which 20-25% is lake trout.
Lake Superior (1990): Achieve…an unspecified yield of other salmonine predators, while maintaining a predator/prey balance that allows normal growth of lake trout.

Non-native salmonines have become a prominent element in the Great Lakes ecosystem and an important concept in Great Lakes fisheries management objectives. The populations of introduced salmonine species are managed to keep alewife abundance below levels associated with the suppression of native fishes, while avoiding wild oscillations in predator-prey ratios and the undermining of the integrity of the ecosystem. In addition, they are also responsible for a substantial economic impact, through the creation of recreational fishing opportunities.

State of the Ecosystem
Non-native salmonine species are stocked in the Great Lakes ecosystem for a dual purpose: 1) to exert a biological control over alewife and rainbow smelt populations (both exotics) and 2) to develop a new recreational fishery (Rand and Stewart, 1998) after decimation of the native top predator (lake trout) by the exotic, predaceous sea lamprey.

Non-native salmonines are used as a tool for alewife control. Alewives are viewed as a nuisance in the system since they prey on the larvae of a variety of native fishes, including yellow perch and lake trout, and because when alewife become very abundant massive die-offs can occur that foul beaches used for recreation. In addition, thiaminase in alewives also has been suggested to cause Early Mortality Syndrome (EMS) in salmonines that consume alewife, which is a threat for lake trout rehabilitation prospects in Lakes Michigan, Huron and Ontario, and

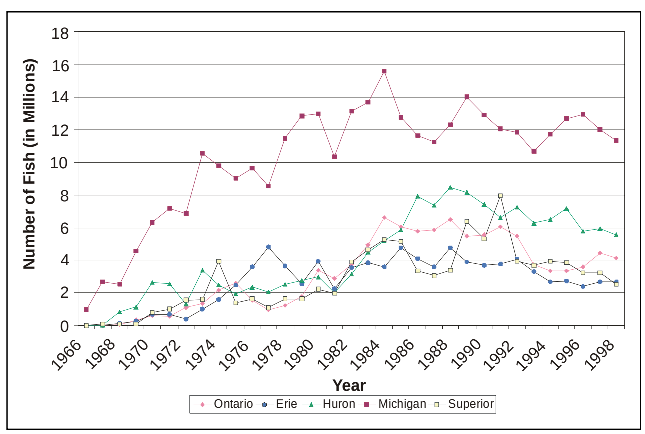

Figure 1. Total number of non-native salmon and trout stocked in the Great Lakes, 1966-1998.
Source: Crawford, 2001

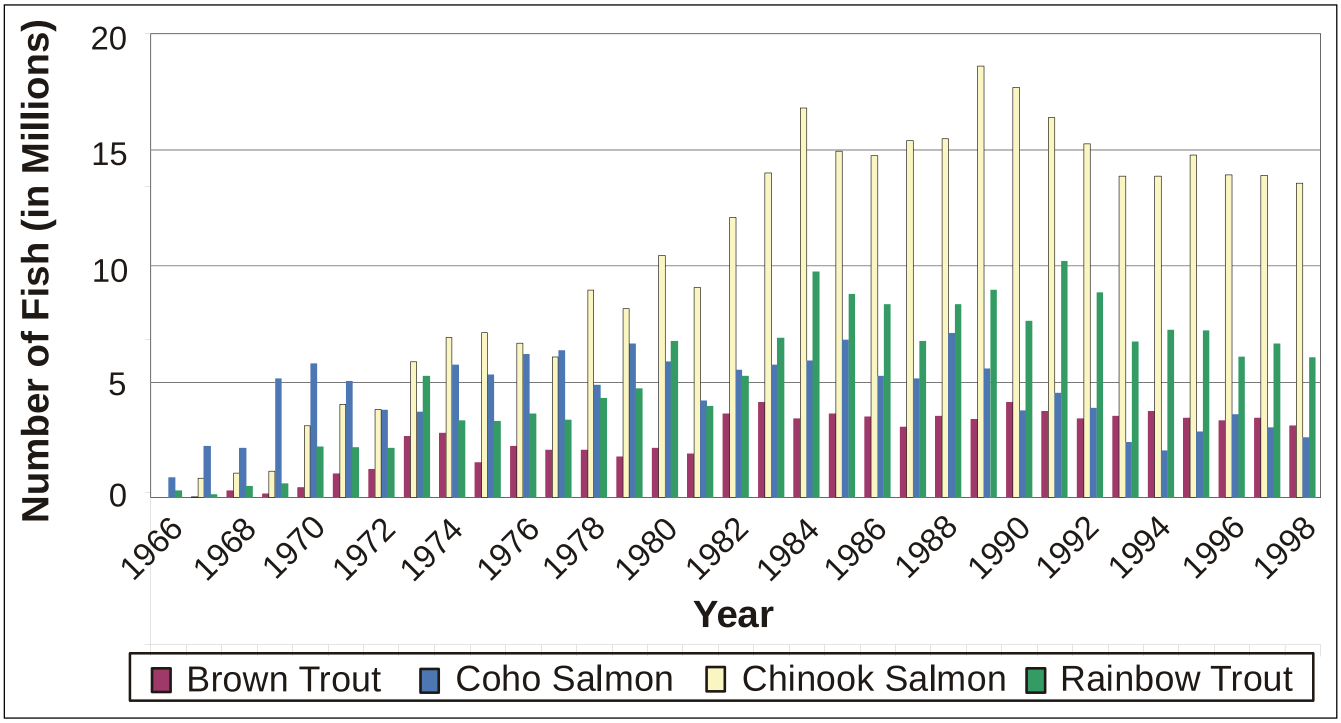

Figure 2. Non-native salmonie stocking by species in the great Lakes, 1966-1998.
Source: Crawford, 2001

Atlantic salmon restoration in Lake Ontario.
A dramatic increase in stocking of non-native salmonines occurred in the 1960s and 1970s, which is now augmented by natural reproduction. It is estimated from stocking data that ~745 million non-native salmonines have been stocked in the Great Lakes basin between 1966 and 1998 (Crawford, 2001).

Figure 1 shows the total amount of non-native salmonine stocking occurring in the Great Lakes basin from 1966-1998. From Figure 1 it is evident that Lake Michigan is the most heavily stocked lake, with a maximum stocking level in 1984 of 15,578,125 fish. In contrast Lake Erie has the lowest rates of stocking, with a maximum of 4,815,303 fish in 1977. Lakes Ontario, Huron and Superior all seem to display a similar trend in stocking, especially in recent years. Since the late 1980s, the number of non-native salmonines stocked in the Great Lakes has been leveling off or slightly declining. This trend can be explained by stocking limits implemented in 1993 by fish managers to lower prey consumption by salmonine species by 50% in Lake Ontario (Schaner *et al*., 2001) and by the implementation of stocking ceilings in Lakes Michigan and Huron, as alewife populations are vulnerable to excessive salmonine predation (Kocik and Jones, 1999).

Figure 2 shows the non-native salmonine stocking by species in the Great Lakes basin from 1966-1998. It is evident from Figure 2 that chinook salmon represents the most heavily stocked non-native salmonine in the Great Lakes basin over the study period, accounting for ~45% of all salmonine releases (Crawford, 2001). Chinook salmon are the least expensive of all non-native salmonines to rear, they also prey almost exclusively on alewife and are thus, the backbone of stocking programs in alewife-infested lakes, such as Lakes Michigan, Huron and Ontario. Like other salmonines, chinook salmon are also stocked in order to provide an economically important sport fishery, which is a need, identified by society. While chinook salmon have the greatest prey demand of all stocked salmonines, an estimated 76, 000 tones of alewife are consumed annually by all salmonine predators (Kocik and Jones, 1999).

Future Pressures
Many of these introduced species are reproducing successfully in portions of the basin, and can be

considered to be "naturalized" components of the ecosystem. Therefore, the question is no longer whether non-native salmonines should be introduced, but rather how to determine the appropriate abundance of salmonine species in this system.

Rand and Stewart (1998), suggest that predatory salmonines have the potential to create a situation where prey (alewife) is limiting and ultimately predator survival is reduced. For example, during the 1990s, chinook salmon in Lake Michigan suffered dramatic declines due to high mortality and high prevalence of Bacterial Kidney Disease (BKD), when alewife was no longer abundant in the prey fish community (Hansen and Holey, 2002). Therefore it is evident that chinook salmon are extremely vulnerable to low alewife abundance. In addition, it is estimated that salmonine predators could have been consuming as much as 53% of alewife biomass in Lake Michigan annually (Brown *et al*., 1999). While suppressing alewife populations, managers must seek to avoid extreme "boom and bust" predator and prey populations, a condition not conducive to biological integrity. The current adaptive management objective is to produce a predator/prey balance by adhering to stocking ceilings established for each lake, based on assessment of forage species and naturally produced salmonines. Alewife populations in the Great Lakes have now become an object of fisheries management concern because of their importance as a forage base for salmonine sport fishery, and to some managers are no longer viewed as a nuisance (Kocik and Jones, 1999). Consequently, with finite prey and habitat resources for salmonine production, each species will exist at some expense to others. To date there is no evidence that current levels of non-native salmonine stocking are an impediment to the restoration of native salmonines; however, there is no guarantee that this will continue to be the case in the future.

Future Activities

Many of these salmonine species are still being stocked in order to maintain an adequate population to suppress non-native prey species (alewife) and for recreational fisheries. It still remains unknown to what extent stocking of these species (where it is still practiced) should continue in order to avoiding oscillations in the forage base of the ecosystem. More research needs to be conducted to determine the optimal number of non-native salmonines, to estimate abundance of naturally produced salmonine species, to assess the abundance of forage species, and to better understand the role of non-native salmonines and exotic prey species in the Great Lakes Ecosystem. Fisheries managers also find it difficult to predict appropriate stocking levels in the Great Lakes basin because there is a delay before stocked salmon become significant consumers of alewife; meanwhile alewife can suffer severe die offs in particularly severe winters. Within a natural ecosystem, there will always be limits to the level of stocking that can be adequately sustained, and this level is based on the balance between bioenergetic demands of both predator and prey (Kocik and Jones, 1999). Chinook salmon will probably continue to be the most abundantly stocked salmonine species in the basin, since they are inexpensive to rear, feed heavily on alewife, and a highly valued by recreational fishers. Fisheries managers should continue to model, assess, and practice adaptive management with the ultimate objective being to meet the "needs identified by society".

Further Work Necessary

Data of both the number of stocked and naturally produced salmonines and of prey fish abundance (alewife) needs to be continually maintained in order for fisheries managers to stock judiciously in implementing adaptive management for predator/prey balance, for recreational fisheries, and for a healthy aquatic ecosystem. This indicator should be reported frequently as salmonine stocking is a complex and dynamic management intervention in the Great Lakes Ecosystem.

Acknowledgments

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Stocking data: Adapted from Crawford (2001). Primary source from the Great Lakes Fishery Commission fish stocking database (1966-1998) received from Mark Holey (U.S. Fish and Wildlife Service), March 2000.

Walleye

SOLEC Indicator #9 - Indicator Matrix

Assessment: Mixed

Purpose

Trends in walleye fishery yields generally reflect changes in walleye health. As a top predator, walleyes can strongly influence overall fish community composition and affect the stability and resiliency of Great Lakes aquatic communities. Therefore, walleye health is a useful indicator of ecosystem health, particularly in moderately productive (mesotrophic) areas of the Great Lakes.

Ecosystem Objective

Protection, enhancement, and restoration of historically important, mesotrophic habitats that support natural stocks of walleye as the top predator fish are necessary for stable, balanced, and productive elements of the Great Lakes ecosystem.

State of the Ecosystem

Reductions in phosphorus loadings during the 1970s substantially improved spawning and nursery habitat for many fish species in the Great Lakes. Improved mesotrophic habitats (i.e., western Lake Erie, Bay of Quinte, Saginaw Bay, and Green Bay) in the 1980s, along with interagency fishery management programs that increased adult survival, led to a dramatic recovery of walleyes in many areas of the Great Lakes, especially in Lake Erie. High water levels also may have played a role in the recovery in some lakes or bays. Annual trends in fishery harvests generally track walleye recovery in these areas, with peak harvests occurring in the mid-1980s to early 1990s followed by declines from the mid-1990s through 2001 in most areas. Total yields were highest in Lake Erie (averaged about 4,700 metric tons, 1975-2001), intermediate in Lakes Huron and Ontario (<300 metric tons in all years), and lowest in Lakes Michigan and Superior (<10 metric tons). Declines after the mid-1990s were likely related to shifts in environmental states (i.e., from mesotrophic to less favorable oligotrophic conditions), less frequent production of strong hatches, changing fisheries, and, perhaps in the case of Lake Erie, a population naturally coming into balance with its prey base. The effects of non-native species on the food web or on walleye behavior (increased water clarity can limit daytime feeding) also may have been a contributing factor. In general, walleye yields peaked under ideal environmental conditions and declined under less favorable (i.e., non-mesotrophic) conditions. Despite recent declines in walleye yields, environmental conditions remain improved relative to the1970s.

Future Pressures

Natural, self-sustaining walleye populations require adequate spawning and nursery habitats. In the Great Lakes, these habitats lie in tributary streams and nearshore reefs, wetlands, and embayments and have been used by native walleye stocks for thousands of years. Degradation or loss of these habitats is the primary concern for the future health of walleye populations and can result from both human causes, as well as from natural environmental variability. Increased human use of nearshore and watershed environments continue to alter the natural hydrologic regime, affecting water quality (i.e., sediment loads) and rate of flow. Environmental factors that affect precipitation patterns ultimately alter water levels, water temperature, water clarity, and flow. Thus, global warming and its subsequent effects on temperature and precipitation in the Great Lakes basin may become increasingly important determinants of walleye health. Non-native invaders, such as zebra and quagga mussels, ruffe, and round gobies continue to disrupt the efficiency of energy transfer through the food web.

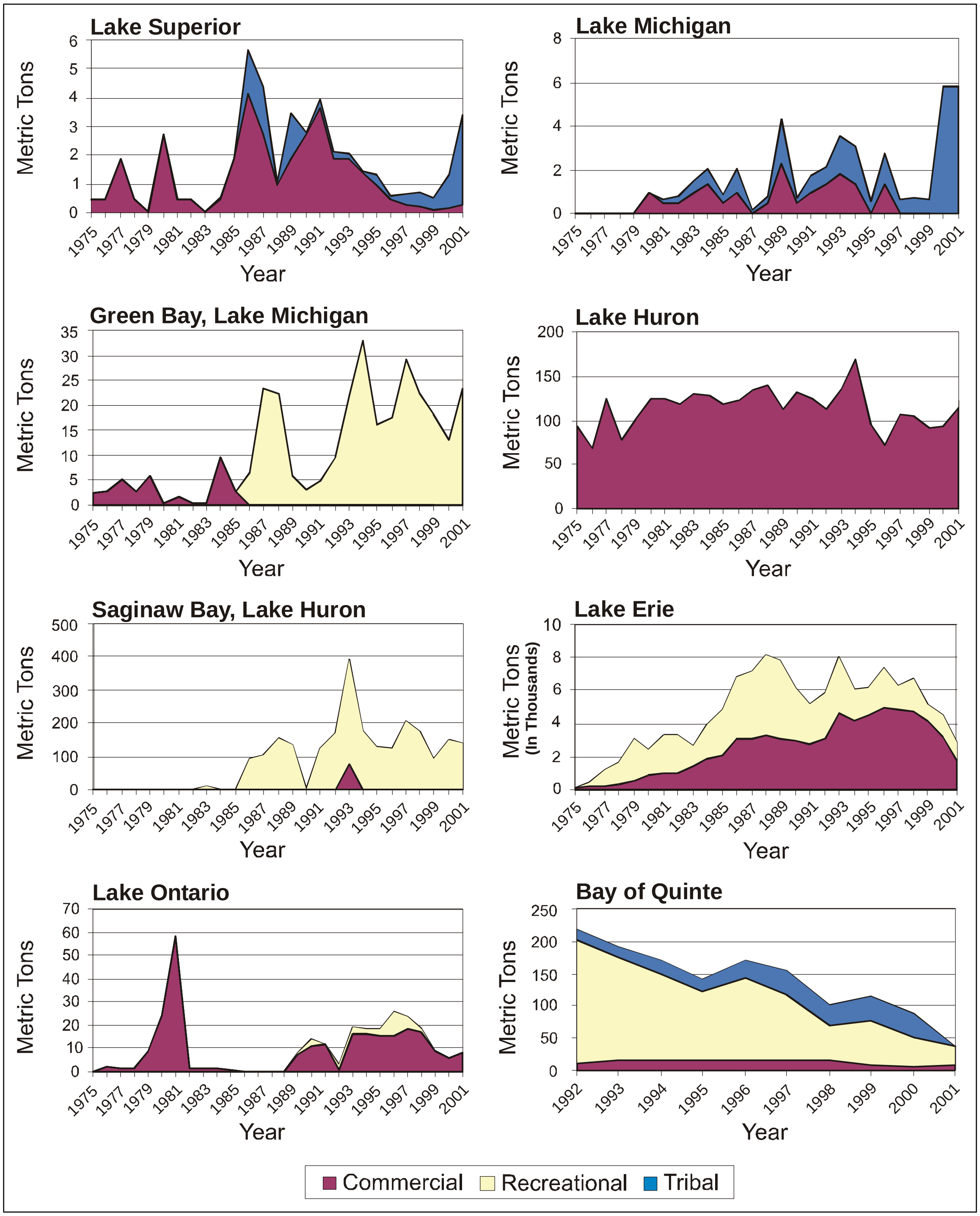

Figure 1. Recreational, commercial and tribal harvest of Walleye from the Great Lakes. Fish community goals and objectives; Lake Huron: 700 metric tons; Lake Michigan: 100-200 metric tons; Lake Erie: sustainable harvest in all basins.

Source: Fishery harvest data were obtained from Tom Stewart and Jim Hoyle (Lake Ontario-OMNR), Tom Eckhart and Steve Lapan (Lakes Ontario-NYDEC), Karen Wright (Upper Lake tribal data-COTFMA), Dave Fielder (Lake Huron-MDNR), Lloyd Mohr (Lake Huron-OMNR), Terry Lychwyck (Green Bay-WDNR), Bruce Morrison (Lake Erie-OMNR), Ken Cullis and Jeff Black (Lake Superior-OMNR), various annual OMNR and ODNR Lake Erie fisheries reports, and the GLFC commercial fishery database

Future Activities
Research is needed to identify further critical reproductive habitats and how they are being affected by environmental and anthropogenic disturbances. This information is crucial to develop management plans that carefully balance human demands with ecosystem health. GIS technology will be the major tool toward this endeavor. Continued development and maintenance of long-term, geo-referenced databases that encompass both ecological and physical aspects of the Great Lakes basin are needed. Ultimately, spatially explicit ecosystem models will be developed to allow better forecasting of system responses to management actions both within and across all Great Lakes.

Further Work Necessary
Fishery yields can serve as appropriate indicators of walleye health but only in a general sense. Yield assessments are lacking for some fisheries (recreational, commercial, or tribal) or in some years for all of the areas. Moreover, measurement units are not standardized among fishery types (i.e., commercial fisheries are measured in pounds while recreational fisheries are typically measured in numbers), which means additional conversions are necessary and may introduce errors. Therefore, trends in yields across time are probably better indicators than absolute values within any year, assuming that any introduced bias is relatively constant over time. Given the above, a 10-year reporting cycle on this indicator may be appropriate, and all agencies should be encouraged to compile walleye harvest data from their major fisheries. In light of serious fiscal constraints now being imposed on virtually all agencies, this recommendation may be difficult to achieve.

Acknowledgments
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Sources
Fishery harvest data were obtained from Tom Stewart and Jim Hoyle (Lake Ontario-OMNR), Tom Eckhart and Steve Lapan (Lake Ontario-NYDEC), Karen Wright (Upper Lakes tribal data-COTFMA), Dave Fielder (Lake Huron-MDNR), Lloyd Mohr (Lake Huron-OMNR), Terry Lychwyck (Green Bay-WDNR), Bruce Morrison (Lake Erie-OMNR), Ken Cullis and Jeff Black (Lake Superior-OMNR), various annual OMNR and ODNR Lake Erie fisheries reports, and the GLFC commercial fishery data base. Fishery data should not be used for purposes outside of this document without first contacting the agencies that collected them.

Hexagenia

SOLEC Indicator #9a - Indicator Matrix

Assessment: Mixed Improving

Purpose
The distribution, abundance, biomass, and annual production of the burrowing mayfly Hexagenia in mesotrophic Great Lakes habitats is measured directly and used as the indicator. *Hexagenia* is used as an indicator of ecosystem health because it is intolerant of pollution and is thus a good reflection of water and lakebed sediment quality in mesotrophic Great Lakes habitats, where it was historically the dominant, large, benthic invertebrate and an important item on the diets of may valuable fishes.

Ecosystem Objective
Historically productive Great Lakes mesotrophic habitats e.g., western Lake Erie; the Bay of Quinte, Lake Ontario; Saginaw Bay, Lake Huron; and Green Bay, Lake Michigan, should be restored and maintained as balanced, stable, and productive elements of the Great Lakes ecosystem with Hexagenia as the dominant, large, benthic invertebrate.

State of the Ecosystem
Major declines in the abundance of *Hexagenia* and low abundance or absence in some Great Lakes habitats where they were historically abundant have been linked to eutrophication and low dissolved oxygen in bottom waters and to pollution of sediments by metals and petroleum products. For example, Hexagenia was abundant in the western and central basins of Lake Erie in the 1930s and 1940s but an extensive mortality occurred in 1953 in the eastern portion of the western basin. The population there recovered in 1954, but extirpation followed throughout the western and central basins by the early 1960s. Improvements in water and sediment quality in historical Hexagenia habitat following the imposition of pollution controls in the 1960s were not immediately followed by the recovery of *Hexagenia* populations. Surveys conducted by the USGS, Great Lakes Science Center in spring 2001 revealed no recovery of *Hexagenia* in Saginaw Bay. Evidence of the beginnings of recovery of *Hexagenia* in Green Bay, and full or nearly full recovery of the population in western Lake Erie, indicate that these mesotrophic

habitats can be considered healthy. Canadian biologists report the recovery of Hexagenia in the Bay of Quinte, Lake Ontario indicating pollution control programs have significantly improved the health of that habitat. Most of Lake St. Clair and portions of the upper Great Lakes connecting channels support populations of *Hexagenia* with the highest biomass and production measured anywhere in North America (Fig. 1). However, *Hexagenia* was extirpated in polluted portions of the St. Marys and Detroit Rivers by the mid-1980s and no recovery has yet been reported for some of these areas.

The recovery of *Hexagenia* in western Lake Erie is a signal event, which shows clearly that properly implemented pollution controls can bring about the recovery of a major Great Lakes mesotrophic ecosystem. With its full recovery, the *Hexagenia* population in western Lake Erie will probably reclaim its functional status as a primary agent in sediment bioturbation and as a trophic integrator directly linking the detrital energy resource to fish, and particularly the economically valuable yellow perch-walleye community. The recovery of *Hexagenia* in western Lake Erie also helps remind us of one outstanding public outreach feature associated with using *Hexagenia* as an indicator of ecosystem health-the massive swarms of winged adults that are typical of healthy, productive *Hexagenia* populations in areas of historical abundance in the Great Lakes. These swarms are highly visible to the public who can use them to judge the success of water pollution control programs and the health of Great Lakes mesotrophic ecosystems.

Future Pressures

The virtual extirpation and delayed recovery of the *Hexagenia* population in western Lake Erie was attributed to the widespread, periodic occurrence of anoxic bottom waters resulting from nutrient inputs in sewage and runoff from agricultural lands, and to toxic pollutants, including oil and heavy metals, which accumulated and persisted in the lakebed sediments. Most point source inputs are now controlled, but in-place pollutants in lakebed sediments appear to be a problem in some areas. Paved surface runoff, spills of pollutants, and combined sewer overflows also pose a major problem in some urban and industrial areas. Phosphorus loadings still exceed guideline levels in some portions

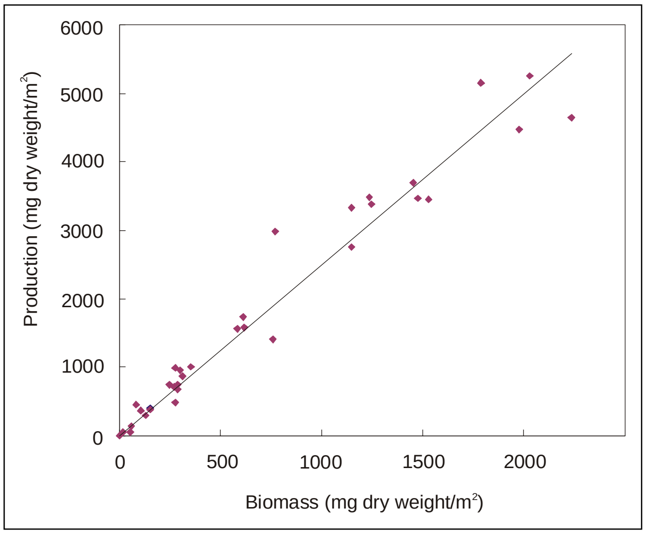

Figure 1. Mean annual biomass and production of *Hexagenia* populations in North America.
Source: T.A. Edsall, R.C. Haas, and J.V. Adams, 2001.

of the Great Lakes and loadings may increase as the human population in the Great Lakes basin grows.

The effects of non-native species on *Hexagenia* and its usefulness as an indicator of ecosystem health are unknown and may be problematic. It has been postulated that the colonization of the western basin of Lake Erie by the zebra mussel (*Dreissena polymorpha*) and the recovery of *Hexagenia* are linked causally, but no specific mechanism has yet been proposed. Support for zebra mussel as a major factor in the recovery of *Hexagenia* in the western basin is perhaps eroded by the fact that Saginaw Bay, Lake Huron, is also heavily colonized by the zebra mussel, but the *Hexagenia* population there, which collapsed in 1955-1956, still has not shown signs of recovery. A survey conducted by the USGS in spring 2001 at 49 stations (total of 140 Ponar grab samples) yielded only one *Hexagenia* nymph.

Future Activities

Regulate point sources and non-point sources of pollution and sharply reduce spills of pollutants in the basin to improve and maintain Great Lakes water and sediment quality consistent with the environmental requirements of healthy, productive populations of *Hexagenia*. Continue development and application of technology and practices designed to restore lakebed and riverbed sediment quality in

Figure 2. Areas of recovery and non-recovery of mayflies (*Hexagenia*) in the Great Lakes.
Source: T.A. Edsall, M.T. Bur, O.T. Gorman, and J.S. Schaeffer, 2002

Areas of Concern (AOCs) and critical *Hexagenia* habitat areas that have problem levels of persistent, in-place pollutants.

Further Work Necessary

1. Develop a monitoring program and collect baseline data for *Hexagenia* populations in all major, historical, Great Lakes mesotrophic habitats so that changes in ecosystem health can be monitored and reported, management strategies evaluated and improved, and corrective actions taken to improve ecosystem health and to judge progress toward reaching interim and long term targets and goals.

2. Implement a new labor-saving monitoring protocol involving sampling in late spring, immediately prior to the annual emergence of adults and washing the samples on a 3.2-mm screen. This approach allows either the number or biomass of the nymphs on the screen to serve as the metric representing the status of the nymphal population and the health of the ecosystem (Fig 2).

3. Conduct studies needed to describe the interactions between *Hexagenia* and introduced aquatic species and the effect of those species, if any, on the utility of *Hexagenia* as an indicator of ecosystem health.

Acknowledgments
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Preyfish Populations

Indicator ID #17 - Indicator Matrix

Assessment: Mixed Deteriorating

Purpose
To directly measure abundance and diversity of preyfish populations, especially in relation to the stability of predator species necessary to maintain the biological integrity of each lake.

Ecosystem Objective
The importance of preyfish populations to support healthy, productive populations of predator fishes is recognized in the FCGOs for each lake. For example, the fish community objectives for Lake Michigan specify that in order to restore an ecologically balanced fish community, a diversity of prey species at population levels matched to primary production and predator demands must be maintained. This indicator also relates to the 1997 Strategic Great Lakes Fisheries Management Plan Common Goal Statement for Great Lakes fisheries agencies.

The preyfish assemblage forms important trophic links in the aquatic ecosystem and constitute the majority of the fish production in the Great Lakes. Preyfish populations in each of the lakes are currently monitored on an annual basis in order to quantify the population dynamics of these important fish stocks leading to a better understanding of the processes that shape the fish community and to identify those characteristics critical to each species. Populations of lake trout, Pacific salmon, and other salmonids in have been established as part of intensive programs designed to rehabilitate (or develop new) game fish populations and commercial fisheries. These economically valuable predator species sustain an increasingly demanding and highly valued fisheries and information on their status is crucial. In turn, these apex predators are sustained by forage fish populations. In addition, the bloater and the lake herring, which are native species, and the rainbow smelt are also directly important to the commercial fishing industry. Therefore, it is very important that the current status and estimated carrying capacity of the preyfish populations be fully understood in order to fully address (1) lake trout restoration goals, (2) stocking projections, (3), present levels of salmonid abundance and (4) commercial fishing interests.

Features

The segment of the Great Lakes' fish communities that we classify as preyfish comprises species – including both pelagic and benthic species – that prey on invertebrates for their entire life history. As adults, preyfish depend on diets of crustacean zooplankton and macroinvertebrates *Diporeia* and *Mysis*. This convention also supports the recognition of particle-size distribution theory and size-dependent ecological processes. Based on size-spectra theory, body size is an indicator of trophic level and the smaller, short-lived fish that constitute the planktivorous fish assemblage discussed here are a discernable trophic group of the food web. At present, bloaters (*Coregonus hoyi*), lake herring (*Coregonus artedi*), rainbow smelt (*Osmerus mordax*), alewife (*Alosa pseudoharengus*), and deepwater sculpins (*Myoxocephalus thompsoni*), and to a lesser degree species like lake whitefish (*Coregonus clupeaformis*), ninespine stickleback (*Pungitius pungitius*) and slimy sculpin (*Cottus cognatus*) constitute the bulk of the preyfish communities.

In Lake Erie, the prey fish community is unique among the Great Lakes in that it is characterized by relatively high species diversity. The prey fish community comprises primarily gizzard shad (*Dorosoma cepedianum*) and alewife (grouped as clupeids), emerald (*Notropis atherinoides*) and spottail shiners (*N. hudsonius*), silver chubs (*Hybopsis storeriana*), trout-perch (*Percopsis omiscomaycus*), round gobies (*Neogobius melanostomus*), and rainbow smelt (grouped as soft-rayed), and age-0 yellow (*Perca flavescens*) and white perch (*Morone americana*), and white bass (*M. chrysops*) (grouped as spiny-rayed).

State of the Ecosystem

Lake Ontario: Alewives and to a lesser degree rainbow smelt dominate the preyfish population. Alewives declined to a low level in 2002 after being driven to intermediate levels in 2000-2001 by an exceptionally strong 1998 year class and a strong 1999 year class; although alewives produced a weak year class in 2000, they produced a strong year class in 2001. Rainbow smelt were at record low levels in 2000-2002; a paucity of large individuals indicates heavy predation pressure. Alewife and rainbow smelt moved to deeper water in the early 1990s when zebra and quagga mussels colonized the lake and they remain in deeper water to this day. Slimy sculpin populations declined coincident with the collapse of *Diporeia* and show no signs of returning to former levels of abundance. No deepwater sculpins were caught in 2000-2001. *Assessment for Lake Ontario: Mixed, deteriorating.*

Lake Erie: The prey fish community in all three basins of Lake Erie has shown declining trends. In the eastern basin, rainbow smelt have shown declines in abundance over the past two decades, although slight increases have occurred in the past couple years. The declines have been attributed to lack of recruitment associated with expanding Driessenid colonization and reductions in productivity. The western and central basins also have shown declines in forage fish abundance associated with declines in abundance of age-0 white perch and rainbow smelt, respectively. The clupeid component of the forage fish community has shown no overall trend in the past decade, although gizzard shad and alewife abundance has been quite variable across the survey period. The biomass estimates for western Lake Erie were based on data from bottom trawl catches, data from acoustic trawl mensuration gear, and depth strata extrapolations (0-6 m, and >6 m). *Assessment for Lake Erie: Mixed, deteriorating.*

Lake Michigan: In recent years, alewife biomass has remained at consistently lower levels compared to the 1970-1980s. Some increase in abundance is noted with strong 1995 and 1998 year classes, but the current low population levels appear to be driven in large part by predation pressure. Rainbow smelt have declined and remain at lower levels, possibly due to predation. Bloater biomass has declined steadily since 1990 and is attributed to a lack of recruitment and slow growth. Bloaters are expected to decline further, but may rebound as part of an anticipated natural cycle in abundance. Sculpins remain at the same level of abundance and continue to contribute a significant

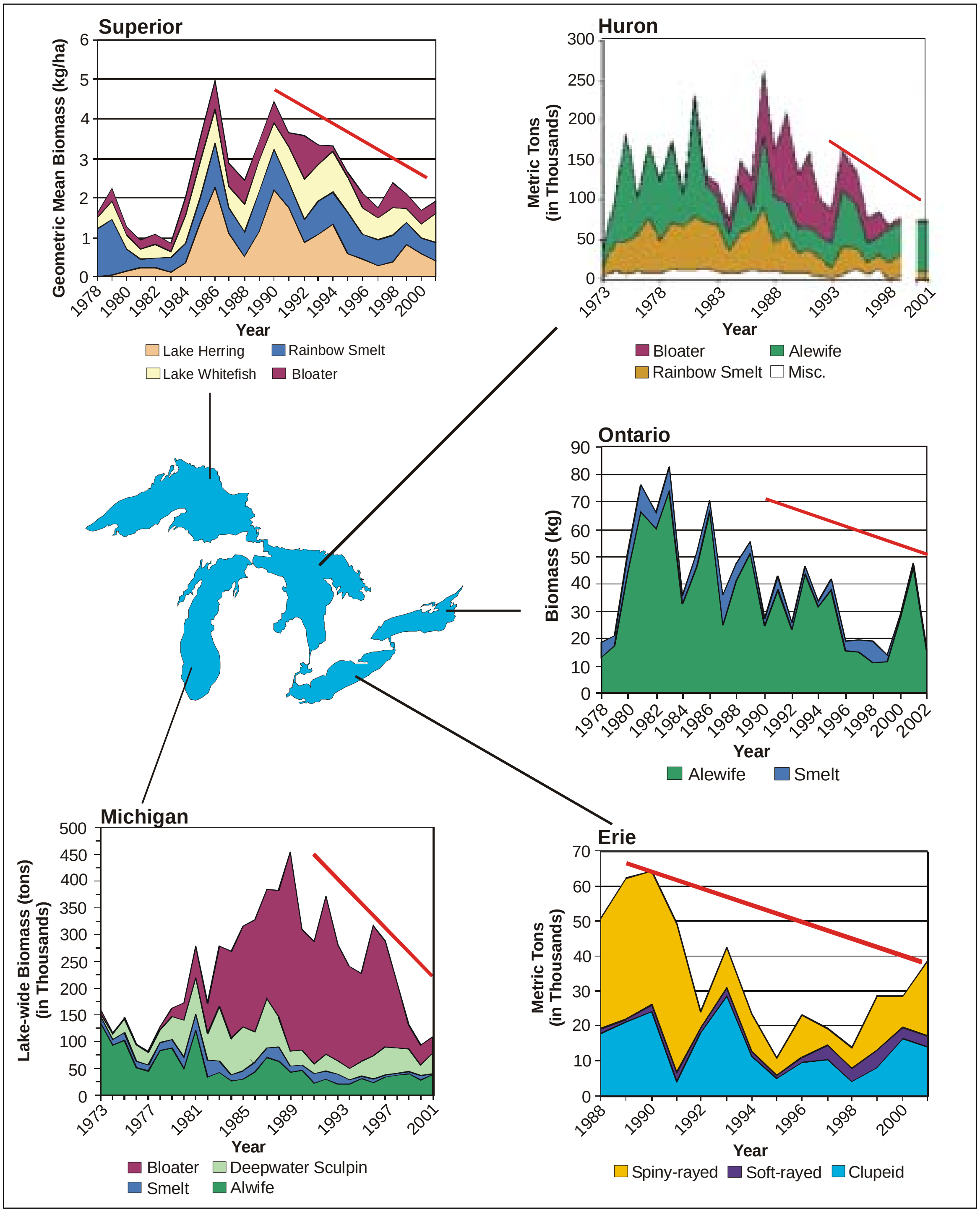

Figure 1. Preyfish population trends in the Great Lakes. The red lines indicate the general trend in overall preyfish populations in each Lake. The measurement reported varies from Lake to Lake, as shown on the vertical scale, and comparisons between Lakes may be misleading. Overall trends over time provide information on relative abundances.

Source: U.S. Geological Survey Great Lakes Science Center, except Lake Erie, which is from surveys conducted by the Ohio Division of Wildlife and the Ontario Ministry of Natural Resources

portion of the preyfish biomass. No age-0 yellow perch were caught in 2001, indicating another failed year class in a series since 1989. Lake-wide biomass of Dreissenid mussels increased between 1999 and 2001 (with the quagga mussel invasion just beginning) while *Diporeia* populations continue to decline. *Assessment for Lake Michigan: Mixed, deteriorating.*

Lake Huron: Similar to Lake Michigan, the decline in bloater abundance has resulted in shift in an increased proportion of alewives in the preyfish community. The changes in the abundance and age structure of the prey for salmon and trout to predominantly younger, smaller fish suggests that predation pressure is an important force in both alewife and rainbow smelt populations. Sculpin populations have varied, but have been at lower levels in recent years. No sampling was conducted in L. Huron in 2000 but was resumed in 2001. In 2001 bloater and rainbow smelt continued to decline in importance while alewife continued to increase due in part to a particularly strong 2001 year class. Alewife regained their position as the dominant preyfish species in Lake Huron, largely as a result of a series of strong year classes since 1998. Whitefish continue to decline from peak levels in the mid 1990s. Overall, the L. Huron fish community is dominated by non-native species, notably alewife. Round gobies and Driessenid mussels are proliferating throughout the lake and increasing in abundance. *Assessment for Lake Huron: Mixed, deteriorating.*

Lake Superior: Over the past 10-15 years, prey fish populations declined in total biomass when compared to the peak years in 1986, 1990, and 1994, a period when lake herring was the dominant prey fish species and wild lake trout populations were starting to recover. Since the early 1980s, dynamics in the total biomass of prey fish has been driven largely by variation in recruitment of age-1 lake herring. Strong year classes in 1984, 1989, and 1998 were largely responsible for peak lake herring biomass in 1986, 1990-1994, and 1999. Biomass of rainbow smelt, the dominant prey fish during 1978-1984, has declined but has been relatively constant over the past 10 years. Bloater biomass has nearly doubled since the early 1980s but like smelt, has been more constant than lake herring. The rise and fall of total prey fish biomass over the period 1984-2001 reflects the recovery of wild lake trout stocks and resumption of commercial harvest of lake herring in Lake Superior. Increases in prey fish populations are not likely without reductions in harvest by predators and commercial fisherman. Other species, notably sculpins, burbot, and stickleback have declined in abundance since the recovery of wild lake trout populations in the mid-1980s. Thus, the current state of the Lake Superior fish community appears to be largely the result of the recovery of wild lake trout stocks coupled with the resumption of human harvest of key prey species. *Assessment for Lake Superior: Mixed, improving.*

Future Pressures

The influences of predation by salmon and trout on preyfish populations appear to be common across all lakes. Additional pressures from *Dreissena* populations are apparent in Lakes Ontario, Erie, and Michigan. "Bottom-up" effects on the prey fishes have already been observed in Lake Ontario following the dreissenid-linked collapse of *Diporeia* and are likely to become apparent in lakes Michigan and Huron as Dreissenids expand and **Diporeia** decline. Furthermore, anecdotal observations in Lake Ontario indicate that *Mysis* are declining as Dreissenids proliferate in profundal waters, suggesting that dynamics of prey fish populations in future years could be driven by bottom-up rather than top-down effects in lakes Michigan, Huron, and Ontario.

Future Activities

Recognition of significant predation effects on preyfish populations has resulted in recent salmon stocking cutbacks in Lakes Michigan, Huron, and Ontario. However, even with a reduced population, alewives have exhibited the ability to produce strong year classes such that the continued judicious use of artificially propagated predators seems necessary to avoid domination by alewife. It should be noted that this is not an option in Lake Superior since lake trout and salmon are largely lake-produced. Potential "bottom-up" effects on prey fishes would be difficult in any attempt to mitigate owing to our inability to affect changes – this scenario only reinforces the need to avoid further introductions of exotics into the Great Lake ecosystems.

Further Work Necessary

It has been advanced that in order to restore an ecologically balanced fish community, a diversity of prey species at population levels matched to primary production and predator demands must be maintained. However, the current mix of native and naturalized prey and predator species, and the contributions of artificially propagated predator species into the system confound any sense of balance in lakes other than Superior. The metrics of ecological balance as the consequence of fish community structure are best defined through food-web interactions. It is through understanding the exchanges of trophic supply and demand that the fish community can be described quantitatively and ecological attributes such as balance can be better defined and the limits inherent to the ecosystem realized.

Continued monitoring of the fish communities and regular assessments of food habits of predators and prey fishes will be required to quantify the food-web dynamics in the Great Lakes. This recommendation is especially supported by continued changes that are occurring not only in the upper but also in the lower trophic levels. Recognized sampling limitations of traditional capture techniques (bottom trawling) has prompted the application of acoustic techniques as another means to estimate absolute abundance of prey fishes in the Great Lakes. Though not an assessment panacea, hydro-acoustics has provided additional insights and has demonstrated utility in the estimates of preyfish biomass.

It is obvious that protecting or reestablishing rare or extirpated members of the once prominent native prey fishes, most notably the various members of the whitefish family (*Coregonus spp*), should be a priority in all the Great Lakes. This recommendation would include the deepwater cisco species and should be reflected in future indicator reports. Lake Superior, whose preyfish assemblage is dominated by indigenous species and retains a full complement of ciscos, should be examined more closely to better understand the trophic ecology of a more natural system.

With the continuous nature of changes that seems to characterize the prey fishes, the appropriate frequency to review this indicator is on a 5-year basis.

Acknowledgments

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Sources

All preyfish trend figures are based on annual bottom trawl surveys performed by USGS Great Lakes Science Center, except the Lake Erie figure, which is from surveys conducted by the Ohio Division of Wildlife and the Ontario Ministry of Natural Resources.

Lake Trout

SOLEC Indicator #93 - Indicator Matrix

Note: This indicator has been split from "Lake Trout and Scud"

Assessment: Mixed

Purpose

This indicator tracks the status and trends in lake trout populations, and will be used to infer the basic structure of the cold water predator community and the general health of the ecosystem. Lake trout were historically the principal salmonine predator in the coldwater communities of the Great Lakes. By the late 1950s, lake trout were extirpated throughout most of the Great Lakes mostly from the combined effects of sea lamprey predation and over fishing. Restoration efforts began in the early 1960s with chemical control of sea lamprey, controls on exploitation, and stocking of hatchery-reared fish to rebuild populations. Full restoration will not be achieved until natural reproduction is established and maintained to sustain populations. To date, only Lake Superior has that distinction.

Ecosystem Objective

Self-sustaining, naturally reproducing populations that support target yields to fisheries are the goal of the lake trout restoration program. Target yields approximate historical levels of lake trout harvest or adjusted to accommodate stocked non-native predators such as Pacific salmon. These targets are 4 million pounds (1.8 million kg) from Lake Superior, 2.5 million pounds (1.1 million kg) from Lake Michigan, 2.0 million pounds (0.9 million kg) from Lake Huron and 0.1 million pounds (0.05 million kg) 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.

State of Ecosystem
Lake trout abundance dramatically increased in all the Great Lakes after initiation of sea lamprey control, stocking, and harvest control. Natural reproduction from large parental stocks of wild fish is occurring throughout Lake Superior supports both onshore and offshore populations, and it may be approaching historical levels. Stocking there has been largely discontinued. Sustained natural reproduction, albeit at low levels, has also been occurring in Lake Ontario since the early 1990s, and in isolated areas of Lake Huron, but has been largely absent elsewhere in the Great Lakes. Parental stock sizes of hatchery-reared fish are relatively high in Lake Ontario and southern Lake Huron and in a few areas of Lake Michigan, but sea lamprey predation, fishery extractions, and low stocking densities have limited population expansion elsewhere.

Future Pressures
Sea lamprey continue to limit population recovery, particularly in northern Lake Huron. Fishing pressures also continue to limit recovery. More stringent controls on fisheries are required to increase survival of stocked fish. In northern Lake Michigan parental stock sizes are low and young in age due to low stocking densities and moderate fishing mortality, hence egg deposition is low in most historically important spawning areas. High biomass of alewives and predators on lake trout spawning reefs are thought to inhibit restoration through egg and fry predation, although the magnitude of this pressure is unclear. A diet dominated by alewives may be limiting fry survival (early mortality syndrome) through thiamine deficiencies. The loss of *Diporeia* and dramatic reductions in the abundance of slimy sculpins is reducing prey for young lake trout and may be affecting survival. Current strains of lake trout stocked may not be appropriate for offshore habitats therefore limiting colonization potential.

Future Activities
Continued sea lamprey control, especially on the St. Marys River is required to increase survival of lake trout to adulthood. New sea lamprey control options, which include pheromone systems that increase trapping efficiency and disrupt reproduction, are being researched and hold promised for improved control. Continued and enhanced control on exploitation is being improved through population modeling in the upper Great Lakes but needs to be applied throughout the basin. Stocking densities need to be increased in some areas, especially in Lake Michigan and the use of alternate strains of lake trout from Lake Superior could be candidates for deep, offshore areas not colonized by traditional strains used for restoration. The relationship between early mortality syndrome and alewives as prey needs to be further investigated to account for inconsistent experimental and empirical results. Directly stocking of yearling or eggs on traditional spawning sites should be used where possible to enhance colonization.

Further Work Necessary
Reporting frequency should be every 5 years. Monitoring systems are in place but in most lakes measures do not directly relate to stated harvest objectives. Objectives may need to be redefined as end points in units measured by the monitoring activities.

Acknowledgments
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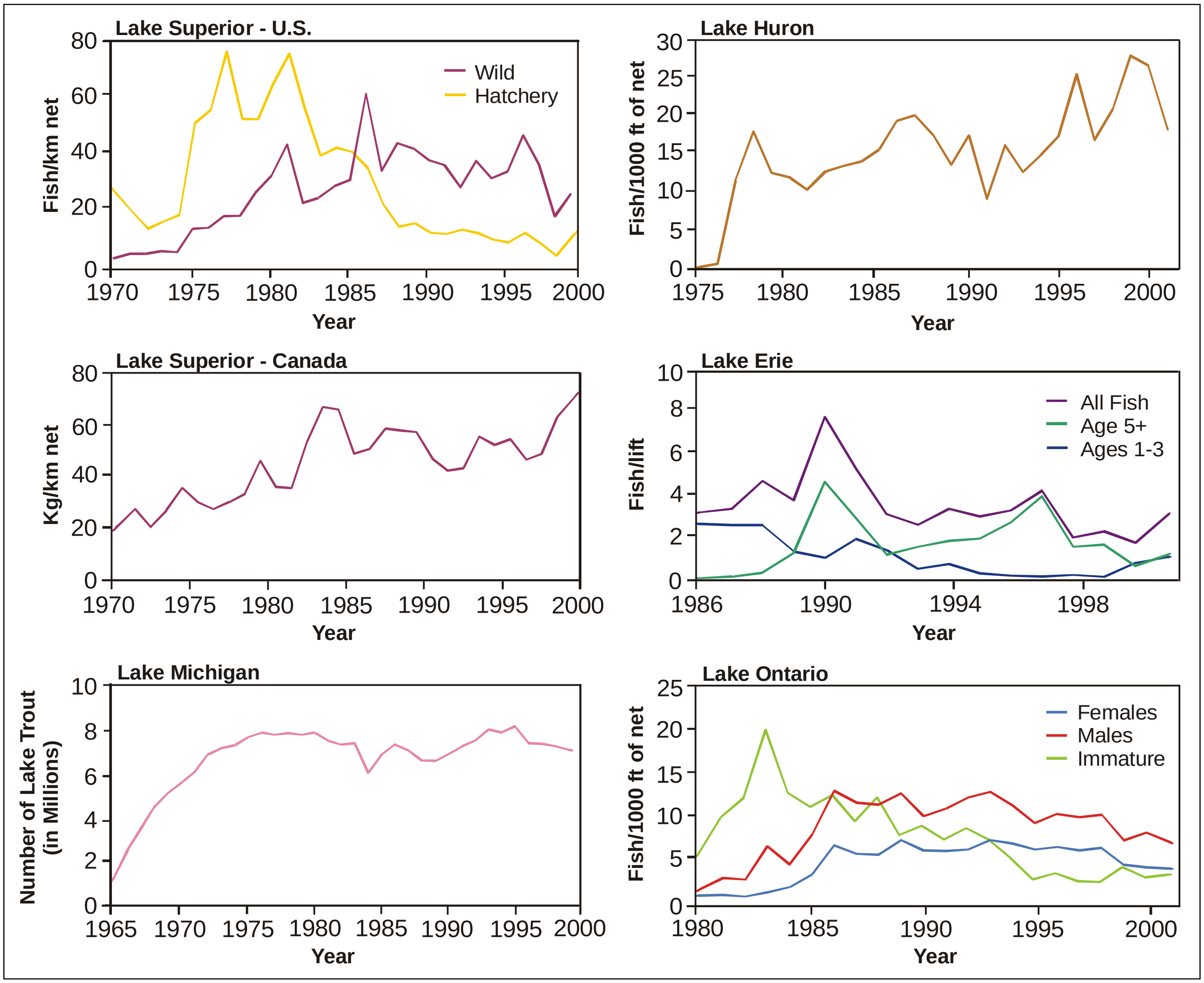

Figure 1. Relative or absolute abundance of lake trout in the Great Lakes. The measurement reported varies from Lake to Lake, as shown on the vertical scale, and comparisons between Lakes may be misleading. Overall trends over time provide information on relative abundances.
Source: U.S. Fish and Wildlife Service

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Abundances of the Benthic Amphipod *Diporeia*

SOLEC Indicator #93a - Indicator Matrix

Note: This indicator has been split from "Lake Trout and Scud" and has a new title

Assessment: Mixed Deteriorating

Purpose

This indicator provides a measure of the biological integrity of the offshore regions of the Great Lakes and consists of assessing the abundance of the benthic macroinvertebrate *Diporeia*. This glacial-marine relict is the most abundant benthic organism in cold, offshore regions (>30 m) of each of the lakes. It is present, but less abundant in nearshore regions of the open lake basins, and is naturally absent from shallow, warm bays, basins, and river mouths. *Diporeia* occurs in the upper few centimeters of bottom sediment and feeds on algal material that freshly settles to the bottom from the water column (i.e. mostly diatoms). In turn, it is fed upon by almost all species of fish. In particular, *Diporeia* is fed upon by many forage fish species, and these species serve as prey for the larger fish such as trout and salmon. For example, sculpin feed almost exclusively upon *Diporeia*, and sculpin are fed upon by lake trout. Also, lake whitefish, an important commercial species, feeds heavily on *Diporeia*. Thus, *Diporeia* is an important pathway by which energy is cycled through the ecosystem, and a key component in the food web of offshore regions. The importance of this organism is recognized in the Great Lakes Water Quality Agreement (Supplement to Annex 1-Specific Objectives).

Ecosystem Objective

The ecosystem objective is to maintain a healthy, stable population of *Diporeia* in offshore regions of the main basins of the Great Lakes, and to maintain at least a presence in nearshore regions. On a broad scale, abundances are directly related to the amount of food settling to the bottom, and population trends reflect the overall productivity of the ecosystem. Abundances can also vary somewhat relative to shifts in predation pressure from changing fish populations. In nearshore regions, this species is sensitive to local sources of pollution.

State of the Ecosystem

Populations of *Diporeia* are currently in a state of dramatic decline in portions of Lakes Michigan, Ontario, Huron, and eastern Lake Erie. Populations appear to be stable in Lake Superior. In all the lakes except Superior, abundances have decreased in both nearshore and offshore areas over the past 12 years, and large areas are now completely devoid of this organism. Areas where *Diporeia* is known to be rare or absent include the southern/southeastern and northern portions of Lake Michigan at depths <70 m (Figure 1), almost all of Lake Ontario (Figure 2) at depths <70 m, the entire southern end of Lake Huron, and the eastern basin of Lake Erie. In other areas of these lakes, *Diporeia* is still present, but abundances are lower than those reported in the 1970s and 1980s. In all the lakes, population declines coincided with the introduction and rapid spread of the zebra mussel, *Dreissena polymorpha*, and the quagga mussel, *Dreissena bugensis*. These two species were introduced into the Great Lakes in the late 1980s via the ballast water of ocean-going ships. Reasons for the negative response of *Diporeia* to these mussel species are not entirely clear. At least one initial hypothesis was that dreissenid mussels were out-competing *Diporeia* for available food. That is, large mussel populations were filtering food material before it reached the bottom, thereby decreasing amounts available to *Diporeia*. More recent evidence suggests that the reason for the decline is more complex than a simple decline in food: 1) *Diporeia* is completely absent from areas where food is still settling to the bottom and where there are no local populations of mussels; 2) the physiological condition of individual animals shows no signs of food deprivation even as population numbers are decreasing.

Future Pressures

As populations of dreissenid mussels continue to expand, it may be expected that declines in *Diporeia* will become more extensive. In the open waters of Lake Michigan, zebra mussels are most abundant at depths of 30-50m, as noted, and *Diporeia* are now gone from lake areas as deep as 70m. Since quagga mussels have recently been found in both Lakes Michigan and

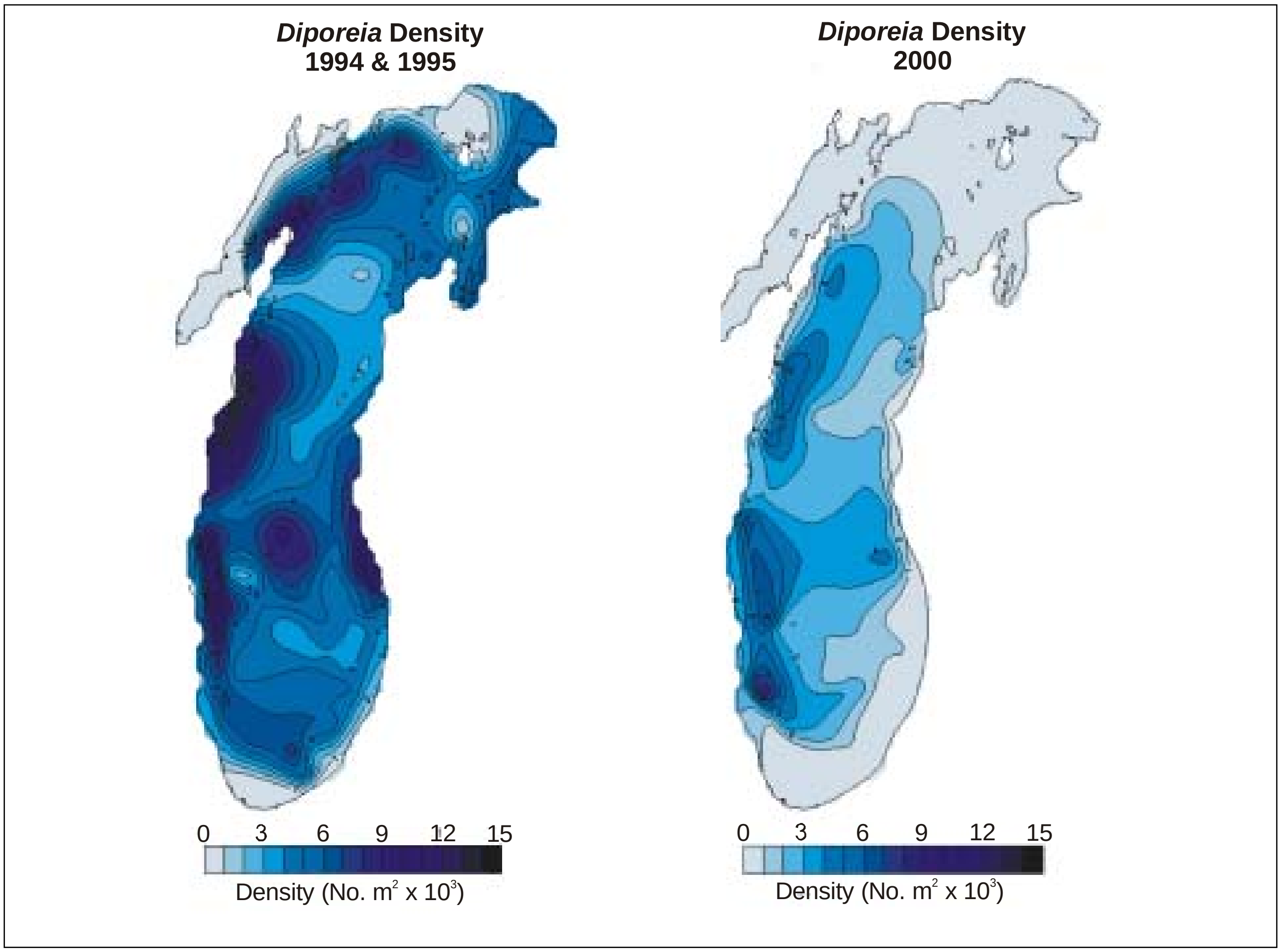

Figure 1. Density (numbers/m^2 x 10^3) of scud (*Diporeia)* in Lake Michigan in 1994-1995 and in 2000. Over the entire Lake, populations declined 68% over this time period.
Source: Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration

Huron, and quagga mussels tend to occur deeper than zebra mussels, the decline or complete loss of Diporeia will likely extend to depths greater than 70m in these two lakes.

Future Activities
Because of its key role in the food web of offshore regions of the Great Lakes, trends in Diporeia populations should be closely monitored. Continued monitoring will not only provide information on the extent of the decline, but also provide a better understanding of linkages to dreissenid populations. In addition, impacts on the offshore food web need to be defined. Recent evidence suggests that fish species most dependent upon *Diporeia* as a food source are being affected. For instance, in Lake Michigan the condition of lake whitefish has declined significantly in areas where *Diporeia* abundances are low.

Further Work Necessary
Because of the rapid rate at which *Diporeia* is declining and its significance to the food web, agencies should report data in a timely manner. The population decline has a defined natural pattern, and studies of food web impacts should be spatially well coordinated. Also, studies to define the cause of the negative response of *Diporeia* to Dreissena should continue. With an understanding of exactly why *Diporeia* populations are declining, we may better predict what additional areas of the lakes are at risk.

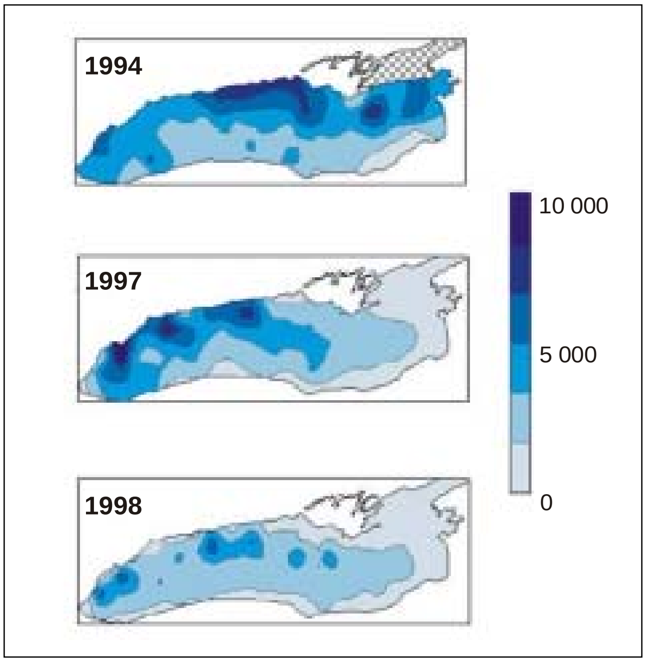

Figure 2. Density (numbers/m^2 x 10^3) of scud (*Diporeia)* in Lake Ontario in 1994, 1997 , and 1998. The cross-hatched area in 1994 indicates no samples taken.
Source: S.J. Lozano, Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration

Acknowledgments

Author: T. F. Nalepa, Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration, Ann Arbor, MI.

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Contribution of *Diporeia* abundances in Lake Ontario (Figure 2) from S.J. Lozano, Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration, Ann Arbor, MI.

Benthic Diversity and Abundance-Aquatic Oligochaete Communities

SOLEC Indicator #104 - Indicator Matrix

Note: This indicator has been *split from "Lake Trout and Scud" and has a new title*

Assessment: Mixed

Purpose

To assess species diversity and abundance of aquatic oligochaete communities in order to determine the trophic status and relative health of benthic communities in the Great Lakes.

Ecosystem Objective

Develop a measure of biological response to organic enrichment of sediments based on Milbrink's (1983) Modified Environmental Index. This measure will have wide application in nearshore, profundal, riverine, and bay habitats of the Great Lakes. This indicator supports Annex 2 of the Great Lakes Water Quality Agreement.

State of the Ecosystem

Shortly after intensive urbanization and industrialization during the first half of the 20th century, pollution abatement programs were initiated in the Great Lakes. Slowly, degraded waters and substrates, especially in shallow areas, began to improve in quality. By the early 1980s, abatement programs and natural biological processes changed habitats to the point where aquatic species tolerant of heavy pollution began to be replaced by species intolerant of heavy pollution.

Use of Milbrink's index values to characterize aquatic oligochaete communities provided one of the earliest measures of habitat quality improvements (e.g., western Lake Erie). This index has been used to measure changing productivity in waters of North America and Europe and, in general, appears to be a reasonable measure of productivity in waters of all the Great Lakes (Figures 1 and 2). Most index values from sites in the upper Lakes are relatively low and fall into the oligotrophic category, whereas index values from sites in known areas of higher productivity (e.g., nearshore southeastern Lake Michigan; Saginaw Bay, Lake Huron) exhibit higher index values. Sites in Lake Erie, which exhibit the highest index values, generally fall in the mesotrophic to eutrophic range, while in Lake Ontario nearshore sites are classified as mesotrophic, and offshore sites are oligotrophic.

Future Pressures

At present, future pressures that may change suitability of habitat for aquatic oligochaete communities are unknown. Undoubtedly, pollution programs and natural processes will continue to improve water and substrate quality. However, measurement of improvements could be overshadowed by things such as zebra and quagga mussels, which were an unknown impact only 10 years ago. Possible pressures include non-point pollution, regional temperature and water level changes, and discharges of contaminants such as pharmaceuticals, as well as from an as yet unforeseen source.

Future Activities

Continued pollution abatement programs aimed at point source pollution will continue to reduce undesirable productivity and past residual pollutants-as a result, substrate quality will improve.

Whatever future ecosystem changes occur in the Great Lakes, it is likely aquatic oligochaete communities will respond early to such changes.

Further Work Necessary

Biological responses of aquatic oligochaete communities are excellent indicators of substrate

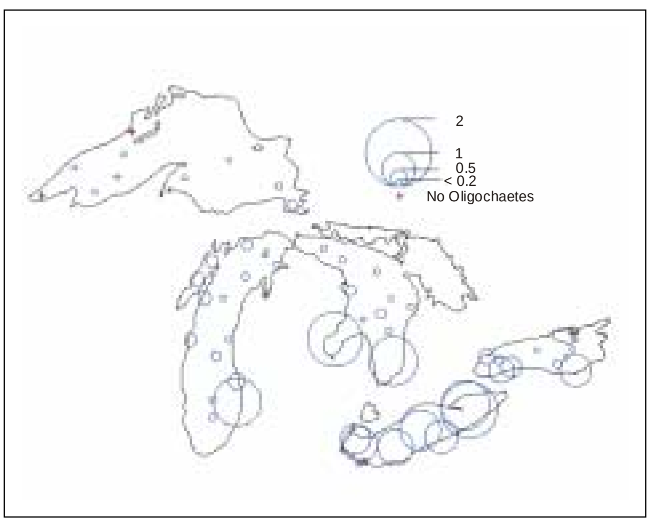

Figure 1. Milbrink's (1983) Modified Environmental Index applied to benthic oligochaete community data from GLNPO's 1999 summer survey.
Source: Barbiero, Richard P. and Marc Tuchman, 2002

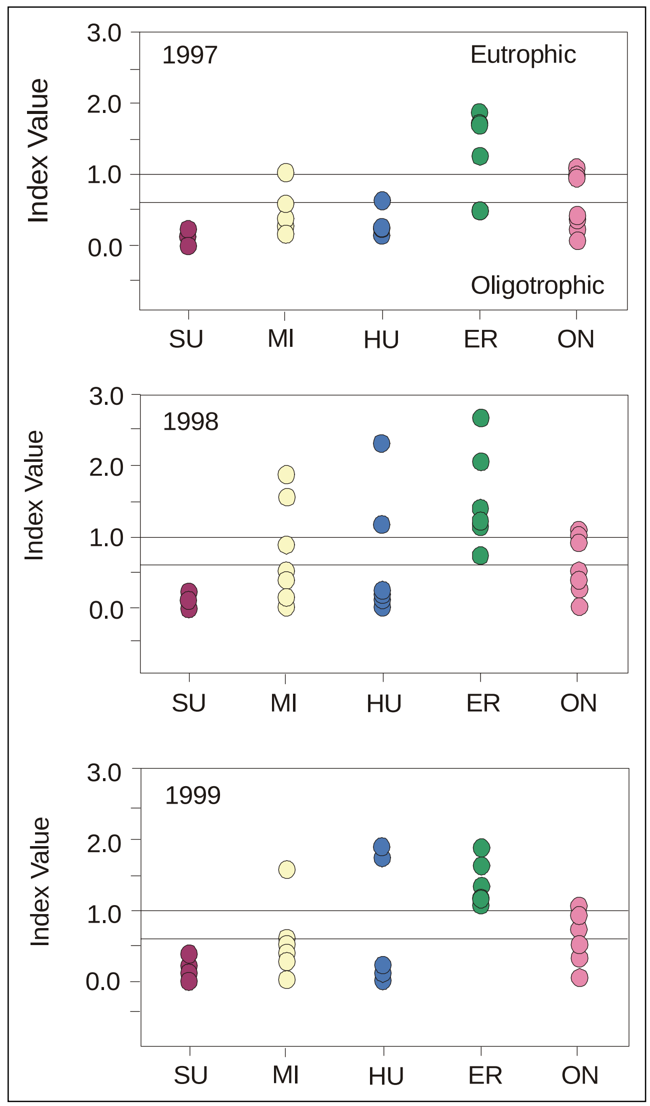

Figure 2. Scatter plots of values of Milbrink's (1983) Modified Environmental Index, applied to data from GLNPO's 1997-1999 summer surveys.
Source: U.S. Environmental Protection Agency, 1997-1999.

quality, and when combined with a temporal component allow the determination of subtle changes in environmental quality, possibly decades before single species indicators. It is only in the past few years, however, that this benthic index has been routinely applied to the open waters of all the Great Lakes. It is therefore critical that routine monitoring of oligochaete communities in the Great Lakes continue. In addition, oligochaete taxonomy is a highly specialized and time consuming discipline, and the classification of individual species responses to organic pollution is continually being up-dated. As future work progresses it is anticipated that the ecological relevance of existing and new species comprising the index will increase. It should be noted that even though this index only addresses responses to organic enrichment in sediments, it may be used with other indicators to assess the effects of other sediment pollutants.

Acknowledgments

Authors: Don W. Schloesser, U.S. Geological Survey, Ann Arbor, MI; Richard P. Barbiero, Dyncorp I & ET, Inc., Chicago, IL, and Mary Beth Giancarlo, USEPA - Great Lakes National Program Office, Chicago, IL.

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Data Source: USEPA Great Lakes National Program Office, Biological Open Water Surveillance Program of the Laurentian Great Lakes, 1997-1999.

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Quality Assurance Project Plan for the Great Lakes Water Quality Surveys, version March 2002, Great Lakes National Program Office-found in the Sampling and Analytical Procedures for GLNPO's Open Lake Water Quality Survey of the **Great Lakes manual, version 2002, GLNPO-contact: Louis Blume, 312-353-2317, blume.louis@epa.gov**

Phytoplankton Populations

SOLEC Indicator #109 - Indicator Matrix

Assessment: Mixed

This assessment is based on historical conditions and expert opinion. Specific objectives or criteria have not been determined.

Purpose

This indicator involves the direct measurement of phytoplankton species composition, biomass, and primary productivity in the Great Lakes, and indirectly assesses the impact of nutrient/ contaminant enrichment and invasive non-native predators on the microbial food-web of the Great Lakes. It assumes that phytoplankton populations respond in quantifiable ways to anthropogenic inputs of both nutrients and contaminants, permitting inferences to be made about system perturbations through the assessment of phytoplankton community size, structure and productivity.

Ecosystem Objective

Desired objectives are phytoplankton biomass size and structure indicative of oligotrophic conditions (i.e. a state of low biological productivity, as is generally found in the cold open waters of large lakes) for Lakes Superior, Huron and Michigan; and of mesotrophic conditions for Lakes Erie and Ontario. In addition, algal biomass should be maintained below that of a nuisance condition in Lakes Erie and Ontario, and in bays and in other areas wherever they occur. There are currently no guidelines in place to define what criteria should be used to assess whether or not these desired states have been achieved.

State of the Ecosystem

Records for Lake Erie indicate that substantial reductions in summer phytoplankton populations occurred in the early 1990's in the western basin. The timing of this decline suggests the possible impact of zebra mussels. In Lake Michigan, a significant increase in the size of summer diatom populations occurred during the 1990's. This is most likely due to the effects of phosphorus reductions on the silica mass balance in this lake, and suggest that diatom populations in this lake might be a sensitive indicator of oligotrophication in Lake Michigan. No trends are apparent in summer phytoplankton

Lakes Huron or Ontario, while only three years of data exist for Lake Superior. Data on primary productivity are no longer being collected.

No assessment of "ecosystem health" is currently possible on the basis of phytoplankton community data, since reference criteria and endpoints have yet to be developed.

It should be noted that these findings are at variance with those reported for SOLEC 2000. This is due to problems with historical data comparability that were unrecognized during the previous reporting period. These problems continue to be worked on, and as such conclusions reported here should be regarded as somewhat provisional.

Future Pressures
The two most important potential future pressures on the phytoplankton community are changes in nutrient loadings and continued introductions and expansions of non-native species. Increases in nutrients can be expected to result in increases in primary productivity and possibly also in increases in phytoplankton biomass. In addition, increases in phosphorus concentrations might result in shifts in phytoplankton community composition away from diatoms and towards other taxa. As seen in Lake Michigan, reductions in phosphorus loading might be expected to have the opposite effect. Continued expansion of zebra mussel populations might be expected to result in reductions in overall phytoplankton biomass, and perhaps also in a shift in species composition, although these potential effects are not clearly understood. It is unclear what effects,

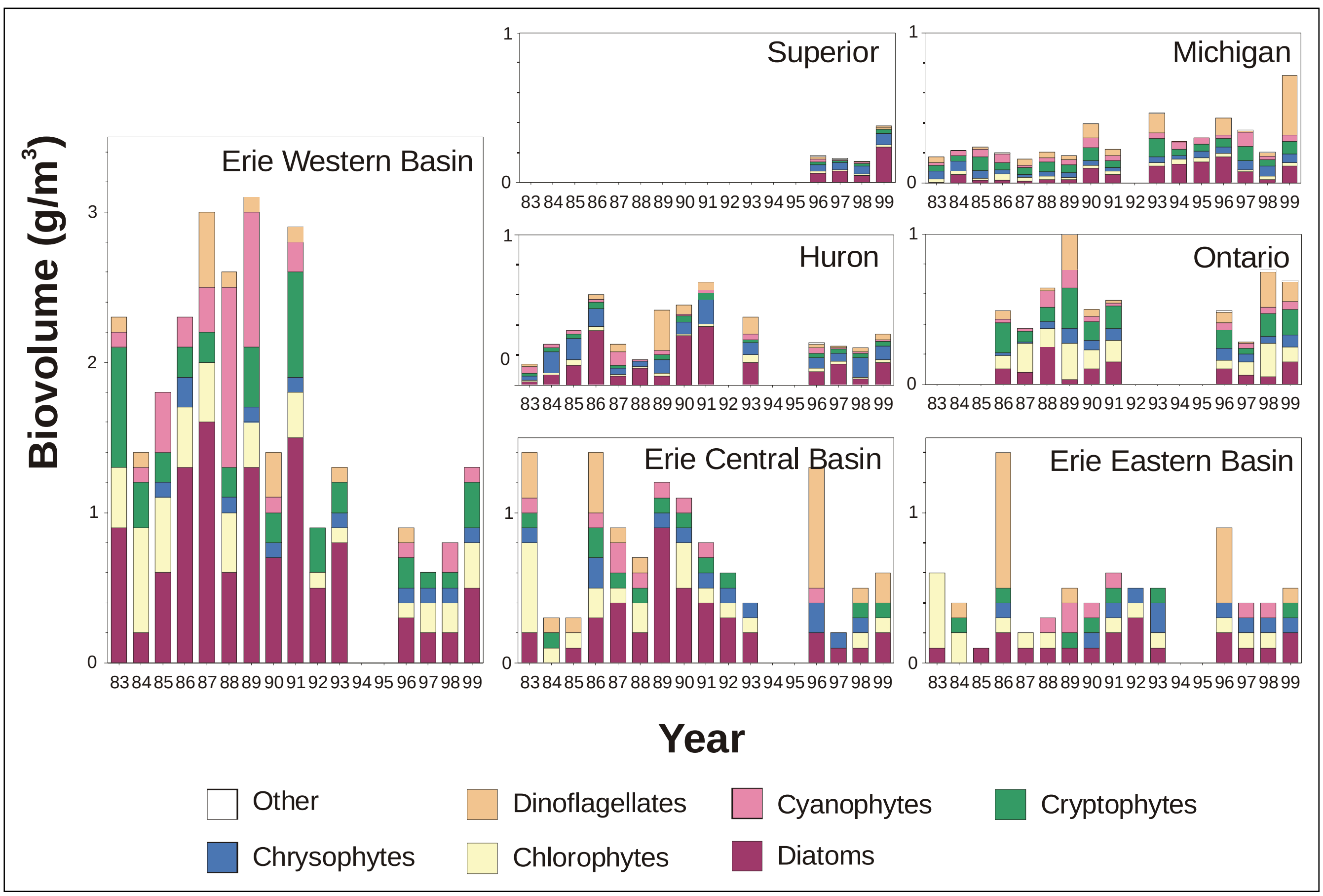

Figure 1. Trends in phytoplankton biovolume (g/m^3) and community composition in the Great Lakes 1983-1999. Samples were collected from offshore, surface waters during August.
Source: U.S. Environmental Protection Agency-Great Lakes National Program Office

if any, might be brought about by changes in the zooplankton community.

Future Actions
The effects of increases in nutrient concentrations tend to become apparent in nearshore areas before offshore areas. The addition of nearshore monitoring to the existing offshore monitoring program might therefore be advisable. Given the greater heterogeneity of the nearshore environment, any such sampling program would need to be carefully thought out, and an adequate number of sampling stations included to enable trends to be discerned.

Further Work Necessary
A highly detailed record of phytoplankton biomass and community structure has accumulated, and continues to be generated, through regular monitoring efforts. However, problems exist with internal comparability of this database. Efforts are currently underway to rectify this situation, and it is essential that the database continue to be refined and improved.

In spite of the existence of this database, its interpretation remains problematic. While the use of phytoplankton data to assess "ecosystem health" is conceptually attractive, there is currently no objective, quantitative mechanism for doing so. Reliance upon literature values for nutrient tolerances or indicator status of individual species is not recommended, since the unusual physical regime of the Great Lakes makes it likely that responses of individual species to their chemical environment in the Great Lakes will vary in fundamental ways from those in other lakes. Therefore, there is an urgent need for the development of an objective, quantifiable index specific to the Great Lakes to permit use of phytoplankton data in the assessment of "ecosystem health".

Acknowledgments
Authors: Richard P. Barbiero, DynCorp, A CSC company, Chcicago, IL, rick.barbiero@dyncorp.com, and Marc L. Tuchman, USEPA GLNPO, Chicago, IL, tuchman.marc@epa.gov.

Sources
U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL, unpublished data.

Zooplankton Populations
SOLEC Indicator #116 - Indicator Matrix

Assessment: Mixed
This indicator report is from 2000. Assessment has been reevaluated in 2003. Specific objectives or criteria for assessment have not been determined.

Purpose
This indicator directly measures changes in community composition, mean individual size and biomass of zooplankton populations in the Great Lakes basin, and indirectly measures zooplankton production as well as changes in food-web dynamics due to changes in vertebrate or invertebrate predation; changes in system productivity, and changes in the type and intensity of predation and in the energy transfer within a system. Suggested metrics include zooplankton mean length, the ratio of calanoid to cladoceran and cyclopoid crustaceans, and zooplankton biomass.

Ecosystem Objective
Ultimately, analysis of this indicator should provide information on the biological integrity of the Great Lakes, and lead to the support of a healthy and diverse fishery. However, the relationship between these objectives and the suggested metrics have not been fully worked out, and no specific criteria have yet been identified for these metrics.

A mean individual size of 0.8 mm has been suggested as "optimal" for zooplankton communities sampled with a 153 mm mesh net, although the meaning of deviations from this objective, and the universality of this objective remain unclear. In particular, questions regarding its applicability to dreissenid impacted systems have been raised.

In general, calanoid/cladoceran+cyclopoid ratios tend to increase with decreasing nutrient enrichment. Therefore high ratios are desirable. As with individual mean size, though, clear objectives have not presently been defined.

State of the Ecosystem
The most recent available data (1998) suggests that mean individual lengths of offshore zooplankton populations in the three upper lakes and the central basin of Lake Erie exceed the objective of 0.8 (Fig. 1),

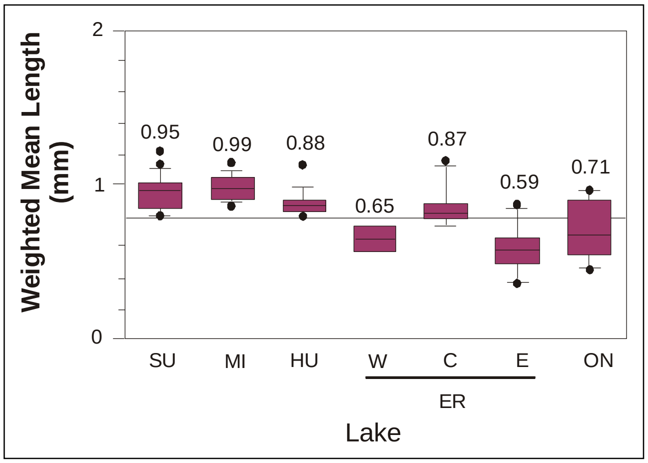

Figure 1. Average individual mean length of zooplankton for the five Great Lakes. Lake Erie is divided into western, central and eastern basins. Length estimates were generated from data collected with 153µm mesh net tows to a depth of 100m or the bottom of the water column, whichever was shallower. Numbers indicate arithmetic averages.
Source: U.S. EPA – GLNPO, August, 1998

suggesting a fish community characterized by a high piscivore/planktivore ratio. Mean individual lengths of zooplankton populations in the western and eastern basins of Lake Erie, as well as most sites in Lake Ontario, were substantially below this objective. Interquartile ranges for most lakes (considering the three basins of Lake Erie separately) were generally on the order of 0.1-0.2 mm, although Lake Ontario was substantially greater.

Historical data from the eastern basin of Lake Erie, from 1985 to 1998, indicate a fair amount of interannual variability, with values from offshore sites ranging from about 0.5 to 0.85 (Fig. 2). As noted above, interpretation of these data are currently problematic.

The ratio of calanoids to cladocerans and cyclopoids showed a clear relationship with trophic state. The average value for the oligotrophic Lake Superior was at least four times as high as that for any other lake, while Lakes Michigan and Huron and the eastern basin of Lake Erie were also high (Fig. 3). The western basin of Lake Erie and Lake Ontario were identically low, while the central basin of Lake Erie had an intermediate value. Historical comparisons of this metric are difficult to make because most historical data on zooplankton populations in the Great Lakes seems to have been generated using shallow (20 m) tows. Calanoid copepods tend to be deep living organisms; therefore the use of data generated from shallow tows would tend to contribute a strong bias to this metric. This problem is largely avoided in Lake Erie, particularly in the western and central basins, where most sites are shallower than 20 m. Comparisons in those two basins have shown a statistically significant increase in the ratio of calanoids to cladocerans and cyclopoids between 1970 and 1983-1987, with this increase sustained throughout the 1990's, and in fact up to the present. A similar increase was seen in the eastern basin, although some of these data were generated from shallow tows, and are therefore subject to doubt.

Future Pressures on the Ecosystem
The zooplankton community might be expected to respond to changes in nutrient concentrations in the lakes, although the potential magnitude of such "bottom up" effects are not well understood. The most immediate potential threat to the zooplankton communities of the Great Lakes is posed by invasive species. An exotic predatory cladoceran, *Bythotrephes cedarstroemii*, has already been in the lakes for over ten

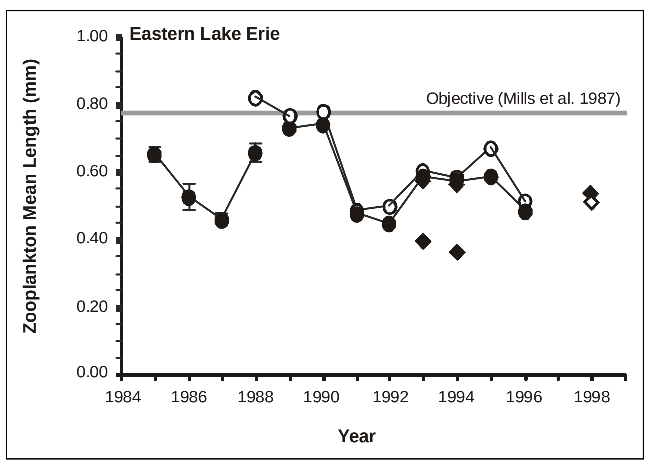

Figure 2. Trend in Jun27-Sep30 mean zooplankton length: NYDEC data (circles) collected with 153µm mesh net, DFP data (diamonds) converted from 64µm to 153µm mesh equivalent. Open symbols = offshore, solid symbols = nearshore (<12m). 1985-1988 are means +/- 1 S.E.
Source: Johannsson *et al.*, 1999

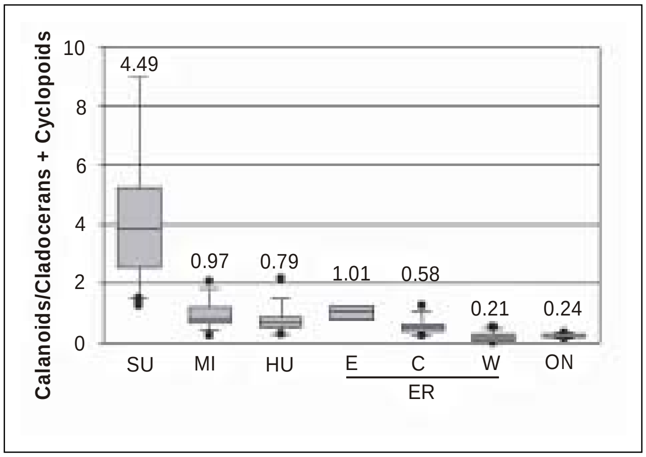

Figure 3. Ratio of biomass of calanoid copepods to that of cladocerans and cyclopoid copepods for the five Great Lakes. Lake Erie (ER) is divided into Western, Central and Eastern basins. (Data collected with 153 µm mesh net tows to a depth of 100 meters of the bottom of the water column, whichever was shallower. Numbers indicate arithmetic averages.
Source: U.S. Environmental Protection Agency-Great Lakes National Program Office, 1998

years, and is suspected to have had a major impact on zooplankton community structure. A second predatory cladoceran, *Cercopagis pengoi*, was first noted in Lake Ontario in 1998, and is expected to spread to the other lakes. In addition, the continued proliferation of dreissenid populations can be expected to impact zooplankton communities both directly through the alteration of the structure of the phytoplankton community, upon which many zooplankton depend for food.

Future Actions

Continued monitoring of the off shore zooplankton communities of the Great Lakes is critical, particularly considering the current expansion of the range of the non-native cladoceran *Cercopagis* and the probability of future invasive zooplankton and fish species.

Further Work Necessary

Currently the most critical need is for the development of quantitative, objective criteria that can be applied to the zooplankton indicator. The applicability of current metrics to the Great Lakes is largely unknown, as are the limits that would correspond to acceptable ecosystem health.

The implementation of a long term monitoring program on the Canadian side is also desirable, to expand both the spatial and the temporal coverage currently provided by American efforts. Since the use of various indices is dependent to a large extent upon the sampling methods employed, coordination between of these two programs, both with regard to sampling dates and locations, and especially with regard to methods, would be highly recommended.

Acknowledgments

This report was prepared by Richard P. Barbiero, DynCorp, A CSC company, Chcicago, IL, rick.barbiero@dyncorp.com, Marc L. Tuchman, USEPA GLNPO, Chicago IL USA, tuchman.marc@epa.gov, and Ora Johannsson, Fisheries and Oceans Canada, Burlington, Ontario Canada.

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Amphibian Diversity and Relative Abundance

SOLEC Indicator #4504 - Indicator Matrix

Assessment: Mixed Deteriorating

Purpose

Assessing species composition and relative abundance of calling frogs and toads in Great Lakes wetlands helps to infer wetland habitat health. A high proportion of the Great Lakes basin's amphibian species inhabit wetlands during part of their life cycle, and many species at risk in the basin are associated with wetlands. Similarly, there is growing international concern about declines of amphibian populations and an apparent increase in deformities. Because frogs and toads are relatively sedentary, have semi-permeable skin, and breed within and adjacent to aquatic systems, they are likely to be more sensitive to, and indicative of, local sources of wetland contamination and degradation than are most other vertebrates.

Geographically extensive and long-term surveys of calling amphibians are possible through coordination of skilled volunteer naturalists in the application of standardized monitoring protocols. Information about abundance, distribution and diversity of amphibians provides needed measures of their population trends, their habitat associations, and can contribute to more effective, long-term conservation strategies.

Ecosystem Objective

The objective is to monitor amphibian communities and gain knowledge about their population dynamics to understand better how to restore and maintain the diversity of Great Lakes wetland amphibian communities, and to sustain breeding amphibian populations across their historical species range.

State of the Ecosystem

Since 1995, Marsh Monitoring Program (MMP) volunteers at 474 routes across the Great Lakes basin have collected amphibian data. Thirteen species were recorded during the 1995 – 2001 period. Spring Peeper was the most frequently detected species (average calling code of 2.5; Table 1) and was frequently recorded in full chorus (Call Level Code 3) where it was encountered. Green Frog was detected in more than half of station-years and average calling code of this species was most often recorded at Call Level 1. Gray Treefrog, American Toad and Northern Leopard Frog were also common, being recorded in more than one-third of all station years. Gray Treefrog was recorded with the second highest average calling code (1.9), indicating that MMP observers usually heard several individuals with some overlapping calls. Bullfrog, Chorus Frog and Wood Frog were detected in approximately one-quarter of station-years. Five species were detected infrequently by MMP surveyors and were recorded in less than 3% of station-years.

Trends in amphibian occurrence were assessed for eight species commonly detected on MMP routes (Figure 1). For each species, annual proportion of stations with that species present at each route were calculated to derive annual indices of occurrence. Overall temporal trend in occurrence for each species was assessed by combining route-level trends in station occurrence. Statistically significant declines in trends were detected for American Toad, Chorus

Species Name	% Station-years present	Average calling code
Spring Peeper	68.4	2.5
Green Frog	54.4	1.3
Gray Treefrog	37.5	1.9
American Toad	35.7	1.5
N. Leopard Frog	31.9	1.3
Bullfrog	25.9	1.3
Chorus Frog	25.5	1.7
Wood Frog	17.9	1.5
Pickerel Frog	2.6	1.1
Fowler's Toad	1.7	1.2
Cope's Gray Treefrog	1.5	1.4
Mink Frog	1.3	1.2
Blanchard's Cricket Frog	0.8	1.4

* MMP Survey stations monitored for multiple years considered as individual samples.

Figure 1. Frequency of occurrence and average Call Level Code for amphibian species detected inside Great Lakes basin MMP stations, 1995 through 2001. Average calling codes area based upon the three level call code standard for all MMP amphibian surveys; surveyors record Code 1 (little overlap among calls, numbers of individuals can be determined), Code 2 (some overlap, numbers can be estimated) or Code 3 (much overlap, too numerous to be estimated).
Source: Marsh Monitoring Program

Frog, and Green Frog. Using water levels of the Great Lakes as a proxy for water conditions throughout the basin, comparisons were made between trends in mean annual water levels of the Great Lakes and trends in amphibian annual station occurrence indices. Some species' trends (Bullfrog, Green Frog, Spring Peeper) appeared to track mean annual lake levels to some degree (Figure 2), whereas others' (American toad, Chorus Frog – not shown) showed no apparent correlation. Differences in habitats, regional population densities, timing of survey visits, annual weather variability, or other additional factors that interplay with water levels might explain variation in species-specific amphibian populations indices.

These data will serve as a baseline with which to compare future survey results, and will lead to a better understanding of the health of Great Lakes amphibian populations and the wetlands that they inhabit. Anecdotal and research evidence suggests that wide variations in inland occurrence of many amphibian species at a given site is a natural and ongoing phenomenon. These variations are apparent for many of the amphibian species monitored during the past seven years. Additional years of data will help reveal whether these observed patterns (e.g. decline in numbers of American Toad and/or Chorus Frog) continue and indicate significant long-term trends. Further data are required to conclude whether Great Lakes wetlands are successfully sustaining amphibian populations. MMP amphibian data are being evaluated to determine how we can gain a better understanding of Great Lakes coastal wetlands health.

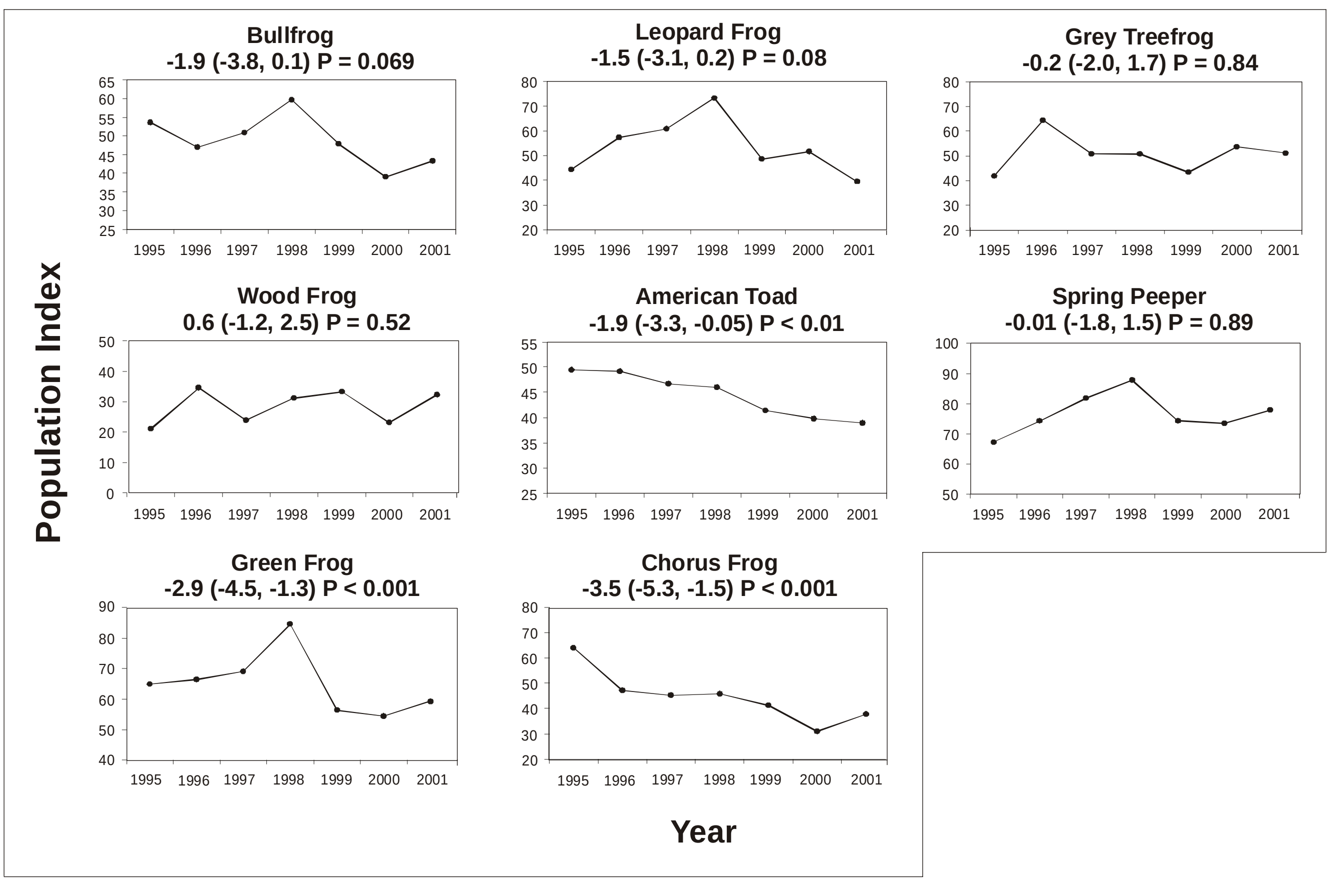

Figure 2. Annual proportion of stations on Marsh Monitoring Program routes at which eight species of amphibians were commonly detected. Data are from 1995-2001.
Source: Marsh Monitoring Program

Future Pressures
Current pressures on this indicator will likely continue. Habitat loss and deterioration remain the predominant threat to Great Lakes amphibian populations. Many coastal and Great Lakes wetlands are at the lowest elevations in watersheds that support very intensive industrial, agricultural and residential development. Even more subtle impacts such as water level stabilization, sedimentation, contaminant and nutrient inputs, and invasion of non-native plants and animals continue to degrade wetlands across the Great Lakes region.

Future Activities
Because of the sensitivity of amphibians to their surrounding environment and growing international concern about their populations, amphibians in the Great Lakes basin and elsewhere continue to be monitored. Wherever possible, efforts should be made to maintain wetland habitats as well as associated upland areas adjacent to coastal wetlands. There is also a need to address more subtle impacts that are detrimental to wetland health such as inputs of toxic chemicals, nutrients and sediments. Restoration programs are underway for many degraded wetland areas through the work of local citizens, organizations and governments. Although significant progress has been made in this area, further programs need to be developed and implemented for many wetland areas that have yet to receive restoration efforts.

Further Work Necessary
Effective monitoring of Great Lakes amphibians requires accumulation of many years of data, using a standardized protocol, over a large geographic expanse. A reporting frequency for this indicator of about five years would be acceptable because amphibian populations naturally fluctuate through time, and a five-year timeframe would likely be able to indicate significant changes in populations. More rigorous studies will relate trends in species occurrence or relative abundance to environmental factors. Reporting will be improved with establishment of a network of survey routes that accurately represent the full spectrum of marsh habitat in the Great Lakes basin. Development of such a network is well underway and three important tasks are already in progress: 1) developing the amphibian indicator as an index for evaluating coastal wetland health; 2) gaining precise geo-referenced locations for all MMP routes to enable future spatial analyses using remote sensing and; 3) continued recruitment efforts and training for volunteer participants. Further work is required to determine the relationship between calling codes used to record amphibian occurrence and count estimates.

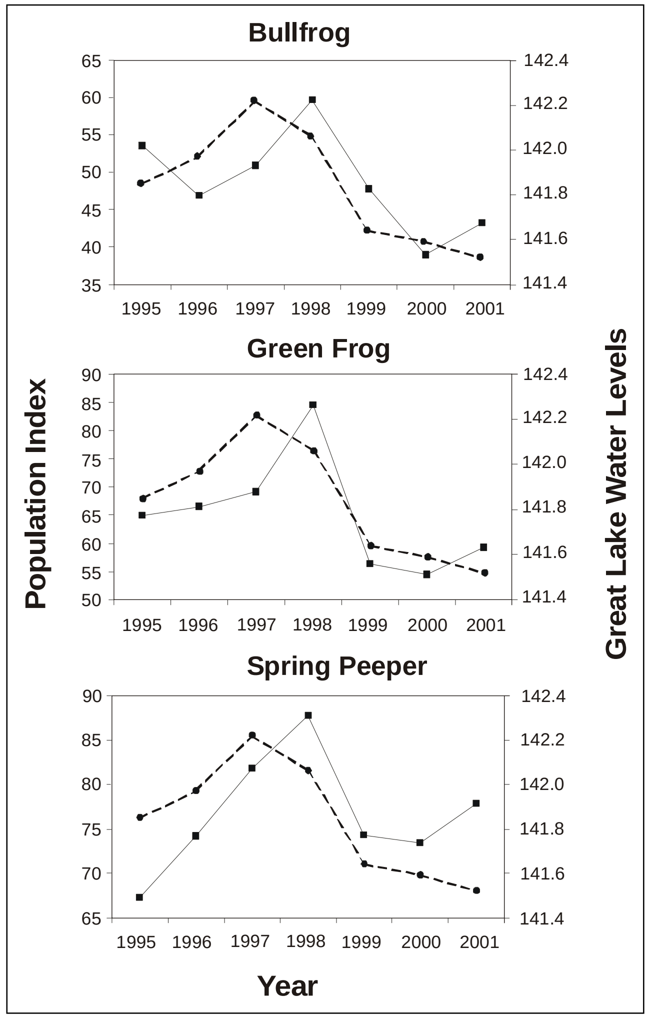

Figure 3. Comparison of mean annual water levels of the Great Lakes (dashed line) and trends in amphibian annual relative occurrence (solid line). These frog populations track average Lake levels to some degree.
Source: Marsh Monitoring Program

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Acknowledgments
Author: Steve Timmermans, Bird Studies Canada.
The Marsh Monitoring Program is delivered by Bird Studies Canada in partnership with Environment Canada's Canadian Wildlife Service and the U.S. Environmental Protection Agency's Great Lakes National Program Office. The contributions of all Marsh Monitoring Program volunteers are gratefully acknowledged.

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Wetland-Dependent Bird Diversity and Relative Abundance

SOLEC Indicator #4507 - Indictor Matrix

Assessment: Mixed Deteriorating

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

Geographically extensive and long-term surveys of wetland-dependent birds are possible through coordination of skilled volunteer naturalists in the application of standardized monitoring protocols. Information about abundance, distribution and diversity of marsh birds provides needed measures of their population trends, their habitat associations, and can contribute to more effective, long-term conservation strategies.

Ecosystem Objective
The objective is to restore and maintain Great Lakes wetland bird community diversity by maintaining and protecting the necessary quantity and quality of wetland habitat.

State of the Ecosystem
From 1995 through 2001, 53 species of birds that use marshes (wetlands dominated by non-woody emergent plants) for feeding, nesting or both were recorded by Marsh Monitoring Program (MMP) volunteers at 434 routes throughout the Great Lakes basin. Among bird species that typically feed in the air above marshes, Tree Swallow and Barn Swallow

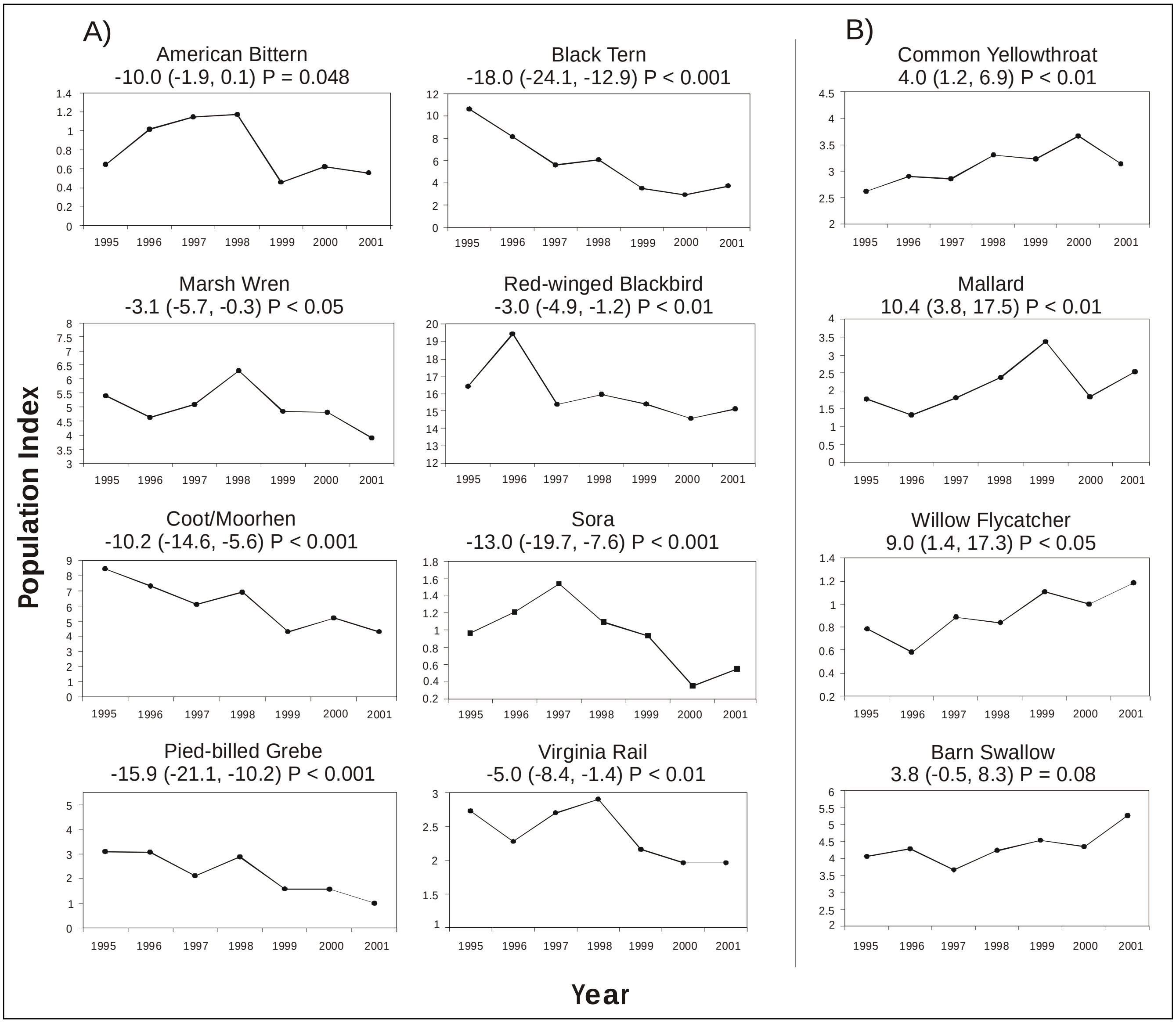

Figure 1. Annual population trends of declining (A) and increasing (B) marsh nesting and aerial foraging bird species detected at Marsh Monitoring Program routes, 1995-2001.
Source: Marsh Monitoring Program

were the two most common. Red-winged Blackbird was the most commonly recorded marsh nesting species, followed by Swamp Sparrow, Common Yellowthroat and Yellow Warbler.

With only seven years of data collected across the Great Lakes basin, the MMP is in its infancy as a long-term population monitoring program. Bird species occurrence and numbers, and their activity and likelihood of being observed, vary naturally among years and within seasons. Trends are presented for several birds recorded at Great Lakes MMP routes (Figure 1a,b). Population indices and trends (i.e., average annual percent change in population index) are presented for species with statistically significant trends, 1995 – 2001. Species with significant basin-wide declines were American Bittern, Black Tern, Marsh Wren, undifferentiated American Coot/ Common Moorhen (calls of these two species are difficult to distinguish from one another), Pied-billed

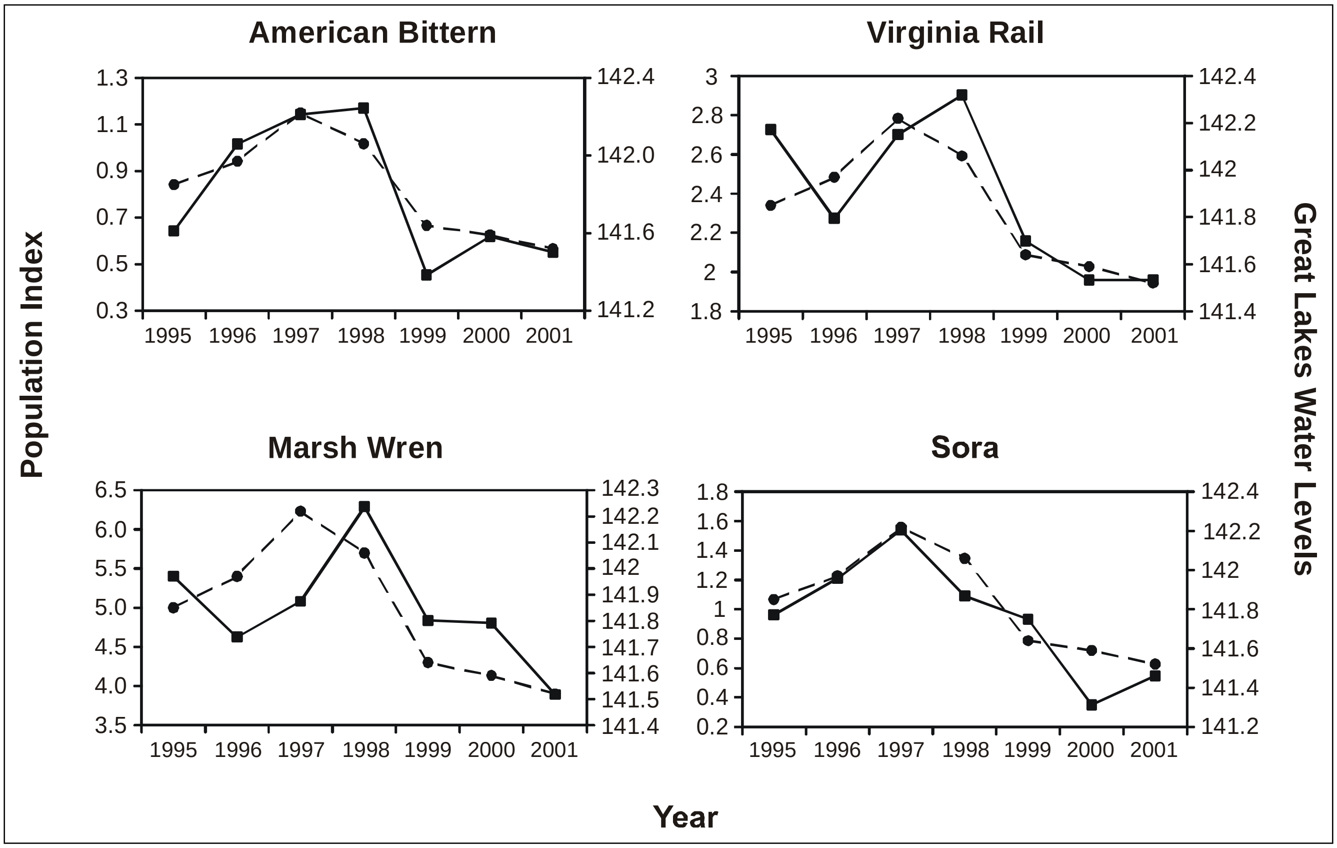

Figure 2. Mean annual water levels of the Great Lakes and trends in wetland bird annual abundance indices.
Source: Marsh Monitoring Program

Grebe, Red-winged Blackbird, Sora, and Virginia Rail (Figure 1a). Statistically significant basin-wide increases were observed for Common Yellowthroat, Mallard, and Willow Flycatcher. Barn Swallow populations increased at a marginally non-significant rate (Figure 1b). Each of the declining species depends on wetlands for breeding but, because they use wetland habitats almost exclusively, Black Tern, American Coot, Common Moorhen, Marsh Wren, Pied-billed Grebe, Sora, and Virginia Rail are particularly dependent on availability of healthy wetlands. Declines in these wetland specialists and increases in some wetland edge and generalist species (e.g., Common Yellowthroat, Willow Flycatcher) suggest possible links to wetland habitat conditions.

To begin investigating this, water levels of the Great Lakes (indicator #4861) were used as a proxy for water conditions throughout the basin, and comparisons were made between trends in mean annual water levels of the Great Lakes and trends in wetland bird annual abundance indices. Some species' trends (American Bittern, Marsh Wren, Sora, and Virginia Rail) appeared to track average lake levels quite closely (Figure 2), whereas others' (e.g., Black Tern, Pied-billed Grebe; not shown) showed no apparent relation with lake levels. Differences in habitats, regional population densities, timing of survey visits, annual weather variability, and other additional factors likely interplay with water levels to explain variation in species-specific bird populations.

Future Pressures

Future pressures on wetland-dependent birds will likely include continuing loss and degradation of important breeding habitats through wetland loss, water level stabilization, sedimentation, contaminant and nutrient inputs, and invasion of non-native plants and animals.

US EPA ARCHIVE DOCUMENT

Future Activities

Wherever possible, efforts should be made to maintain high quality wetland habitats and adjacent upland areas. There is also a need to address more subtle impacts that are detrimental to wetland health such as water level stabilization, invasive species and inputs of toxic chemicals, nutrients and sediments. Restoration programs are underway for many degraded wetland areas through the work of local citizens, organizations and governments. Although significant progress has been made, further conservation and restoration work is needed.

Further Work Necessary

Monitoring will continue across the Great Lakes basin. Continued monitoring of at least 100 routes through 2006 is projected to provide good resolution for most of the wetland-dependent birds recorded by the MMP. Recruitment and retention of program participants will therefore continue to be a high priority. Further work is necessary to establish endpoints and acceptable thresholds for bird diversity and abundance. Work is underway to ascertain marsh bird habitat associations using MMP bird and habitat data. Three additional important tasks are already in progress: 1) developing the wetland bird indicator as an index for evaluating coastal wetland health; 2) gaining precise geo-referenced locations for all MMP routes to enable future spatial analyses using remote sensing, and; 3) continued recruitment efforts and training for volunteer participants. Assessments of relationships among count indices, bird population parameters, and critical environmental factors are also needed.

Although more frequent updates are possible, reporting trend estimates every five or six years is most appropriate for this indicator. A variety of efforts are underway to enhance reporting breadth and efficiency.

Acknowledgments

Author: Steve Timmermans, Bird Studies Canada.
The Marsh Monitoring Program is delivered by Bird Studies Canada in partnership with Environment Canada's Canadian Wildlife Service and the United States Environmental Protection Agency's Great Lakes National Program Office. The contributions of all Marsh Monitoring volunteers are gratefully acknowledged.

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Area, Quality and Protection of Alvar Communities

SOLEC Indicator #8129 (alvar) - Indicator Matrix
Note: this indicator report is from 2000

Assessment: Mixed

Purpose
This indicator assesses the status of one of the 12 special lakeshore communities identified within the nearshore terrestrial area. Alvar communities are naturally open habitats occurring on flat limestone bedrock. They have a distinctive set of plant species and vegetative associations, and include many species of plants, mollusks, and invertebrates that are rare elsewhere in the basin. All 15 types of alvars and associated habitats are globally imperiled or rare. Over 2/3 of known alvar occurrences within the Great Lakes Basin are close to the shoreline.

Ecosystem Objective
Conservation of alvar communities relates to IJC Desired Outcome 6: Biological Community Integrity and Diversity. A four-year study of Great Lakes alvars completed in 1998 (the International Alvar Conservation Initiative-IACI) evaluated conservation targets for alvar communities, and concluded that essentially all of the existing viable occurrences should be maintained, since all types are below the minimum threshold of 30-60 viable examples. As well as conserving these ecologically distinct communities, this target would protect populations of dozens of globally significant and disjunct species. A few species, such as Lakeside Daisy (*Hymenoxis herbacea*) and the beetle *Chlaenius p. purpuricollis*, have nearly all of their global occurrences within Great Lakes alvar sites.

State of the Ecosystem
Alvar habitats have likely always been sparsely distributed, but more than 90% of their original extent has been destroyed or substantially degraded by agriculture and other human uses. Approximately 64% of the remaining alvar area occurs within Ontario, with about 16% in New York State, 15% in Michigan, 4% in Ohio, and smaller areas in Wisconsin and Quebec.

Data from the IACI and state/provincial alvar studies was screened and updated to identify viable community occurrences. Just over 2/3 of known Great Lakes alvars occur close to the shoreline, with all or a substantial portion of their area within 1 km of the shore.

Note that typically several different community types occur within each alvar site.

Among the 15 community types documented, six types show a strong association (over 80% of their acreage) with nearshore settings. Four types have less than half of their occurrences in nearshore settings.

The current status of all nearshore alvar communities was evaluated by considering current land ownership and the type and severity of threats to their integrity. As shown in the figure, less than 1/5th of the nearshore alvar acreage is currently fully protected, while over 3/5th is at high risk.

	Total in Basin	Nearshore
No. of alvar sites	82	52
No. of community occurences	204	138
Alvar acreage	28 475	20 009

Figure 1. Number of Alvar sites/communities found near-shore and total in the basin
Source: Ron Reid, Bobolink Enterprises

The degree of protection for nearshore alvar communities varies considerably among jurisdictions. For example, Michigan has 66% of its nearshore alvar acreage in the Fully Protected category, while Ontario has only 7%. In part, this is a reflection of the much larger total shoreline acreage in Ontario, as shown in the following figure. (Other states have too few nearshore sites to allow comparison).

Each alvar community occurrence has been assigned an "EO rank" to reflect its relative quality and condition. A and B-ranks are considered viable, while C-ranks are marginal. As shown in the following figure, protection efforts to secure alvars have clearly focused on the best quality sites.

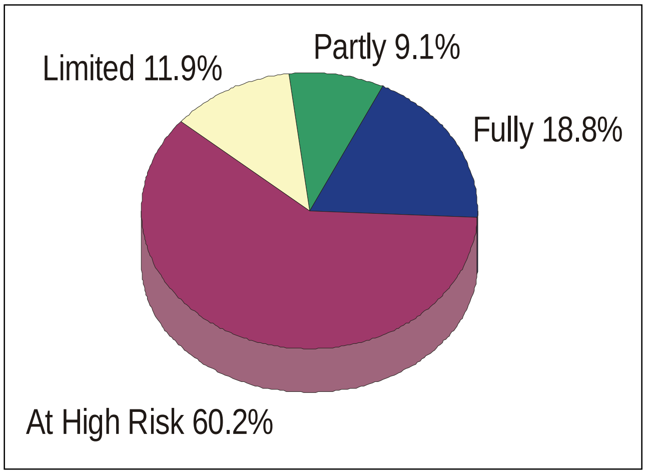

Figure 2. Protection Status 2000. Nearshore alvar acreage.
Source: Ron Reid, Bobolink Enterprises

Pressure on the Ecosystem

Nearshore alvar communities are most frequently threatened by habitat fragmentation and loss, trails and off-road vehicles, resource extraction uses such as quarrying or logging, and adjacent land uses such as residential subdivisions. Less frequent threats include grazing or deer browsing, plant collecting for bonsai or other hobbies, and invasion by non-native plants such as European Buckthorn and Dog-strangling Vine.

Recent Progress

Documentation of the extent and quality of alvars through the IACI has been a major step forward, and has stimulated much greater public awareness and conservation activity for these habitats. Over the past two years, a total of 10 securement projects has resulted in protection of at least 5289.5 acres of alvars across the Great Lakes basin, with 3344.5 acres of that within the nearshore area. Most of the secured nearshore area is through land acquisition, but 56 acres on Pelee Island (ON) are through a conservation easement, and 1.5 acres on Kelleys Island (OH) are through State dedication of a nature reserve. These projects have increased the area of protected alvar dramatically in a short time.

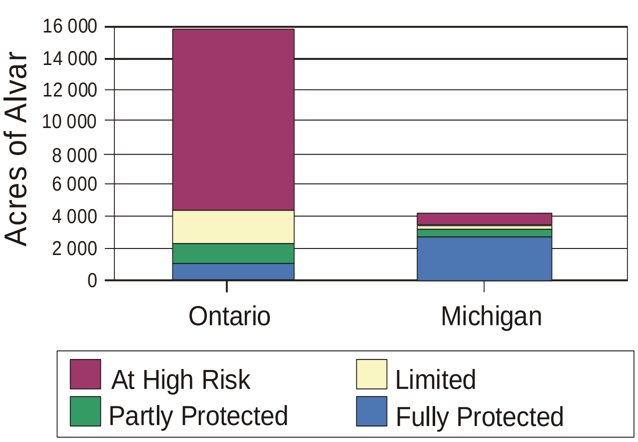

Figure 3. Comparison of acreage protected. Nearshore alvars: Ontario and Michigan.
Source: Ron Reid, Bobolink Enterprises

Future Actions

Because of the large number of significant alvar communities at risk, particularly in Ontario, their status should be closely watched to ensure that they are not lost. Major binational projects hold great promise for further progress, since alvars are a Great Lakes resource, but most of the unprotected area is within Ontario. Projects could be usefully modeled after the 1999 Manitoulin Island (ON) acquisition of 17,000 acres through a cooperative project of The Nature Conservancy of Canada, The Nature Conservancy, Federation of Ontario Naturalists, and Ontario Ministry of Natural Resources.

Acknowledgments

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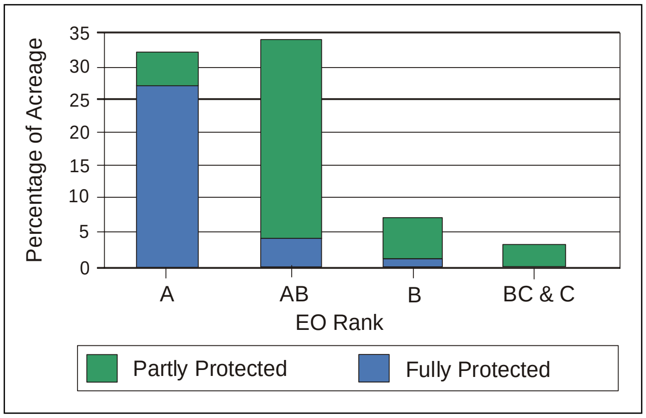

Figure 4. Protection of high quality alvars.
Source: Ron Reid, Bobolink Enterprises

1.2 STATE INDICATOR REPORTS-PART 2

SUMMARY OF STATE INDICATORS-PART 2

The overall assessment for the State indicators is incomplete. Part One of this Assessment presents the indicators for which we have the most comprehensive and current basin-wide information. Data presented in Part Two of this report represent indicators for which information is not available year to year or are not basin-wide across jurisdictions. Within the Great Lakes indicator suite, 38 have yet to be reported, or require further development. In a few cases, indicator reports have been included that were prepared for SOLEC 2000, but that were not updated for SOLEC 2002. The information about those indicators is believed to be still valid, and therefore appropriate to be considered in the assessment of the Great Lakes. In other cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

Indicator Name	Assessment in 2000	Assessment in 2002
Native Freshwater Mussels	Mixed, deteriorating	Not Assessed
Urban Density	Unable to Assess	Mixed, deteriorating (for Lake Superior basin)
Economic Prosperity	Mixed	Mixed (for Lake Superior basin)
Area, Quality and Protection of Great Lakes Islands	No Report	Not Assessed

Green represents an improvement of the indicator assessment from 2000.
Red represents deterioration of the indicator assessment from 2000.
Black represents no change in the indicator assessment from 2000, or where no previous assessment exists.

Native Freshwater Mussels

SOLEC Indicator #68 - Indicator Matrix
Note: title has been changed from Native Unionid Mussels

Assessment: Not Assessed

Data are not system-wide.

Purpose

The purpose of this indicator is to report on the location and status of freshwater mussel (unionid) populations and their habitats throughout the Great Lakes system, with emphasis on endangered and threatened species. This information will be used to direct research aimed at identifying the factors responsible for mussel survival in refuge areas, which in turn will be used to predict the locations of other natural sanctuaries and guide their management for the protection and restoration of Great Lakes mussels.

Ecosystem Objective

Restoration of the richness, distribution, and abundance of mussels throughout the Great Lakes reflecting the general health of the basin ecosystems. The long-term goal is for mussel populations to be stable and self-sustaining wherever possible throughout their historical range in the Great Lakes, including the connecting channels and tributaries.

State of the Ecosystem

Freshwater mussels (Bivalvia: Unionacea) are of unique ecological value as natural biological filters, food for fish and wildlife, and indicators of good water quality. In the United States, some species are commercially harvested for their shells and pearls. These slow-growing, long-lived organisms can influence ecosystem function such as phytoplankton ecology, water quality, and nutrient cycling. As our largest freshwater invertebrate, freshwater mussels may also constitute a significant proportion of the large freshwater invertebrate biomass. Because they are sensitive to toxic chemicals, mussels may serve as an early-warning system to alert us of water quality problems. They are also good indicators of environmental change due to their longevity and sedentary nature. Since mussels are parasitic on fish during their larval stage, they depend on healthy fish communities for their survival.

The richness, distribution, and abundance of mussels reflect the general health of aquatic ecosystems. They are a particularly sensitive indicator of biofouling by the non-native zebra mussel, Dreissena polymorpha. Freshwater mussels, like butterflies, were prized by amateur collectors and naturalists in the past. As a result, many museums have extensive shell collections dating back 150 years or more that provide us with an invaluable “window to the past” that is not available for other aquatic invertebrates.

Freshwater mussels have severely declined across North America, particularly in the Great Lakes. A number of species listed as endangered or threatened in the United States or Canada, or in individual states (freshwater mussels are not considered for provincial listing at present), are found in the Great Lakes. In the United States, these include the clubshell (Pleurobema clava), fat pocketbook (Potamilus capax), northern riffleshell (Epioblasma torulosa rangiana), and white catspaw (Epioblasma obliquata perobliqua). In Canada, the northern riffleshell, rayed bean (Villosa fabalis), wavy-rayed lampmussel (Lampsilis fasciola), mudpuppy mussel (Simpsonaias ambigua), snuffbox (Epioblasma triquetra), round hickorynut (Obovaria subrotunda) and kidneyshell (Ptychobranchus fasciolaris) are listed as endangered.

Nearly 300 species of freshwater mussels are native to the rivers, streams and lakes of North America. This is the richest freshwater mussel fauna in the world, representing one-third of all described species. Unfortunately, freshwater mussels are also one of the most endangered groups of organisms on the continent, with nearly 72% of species vulnerable to extinction or already extinct. The decline of unionids has been attributed to commercial exploitation, water quality degradation (pollution, siltation), habitat destruction (dams, dredging, channelization), riparian and wetland alterations, changes in the distribution and/ or abundance of host fishes, and non-native species.

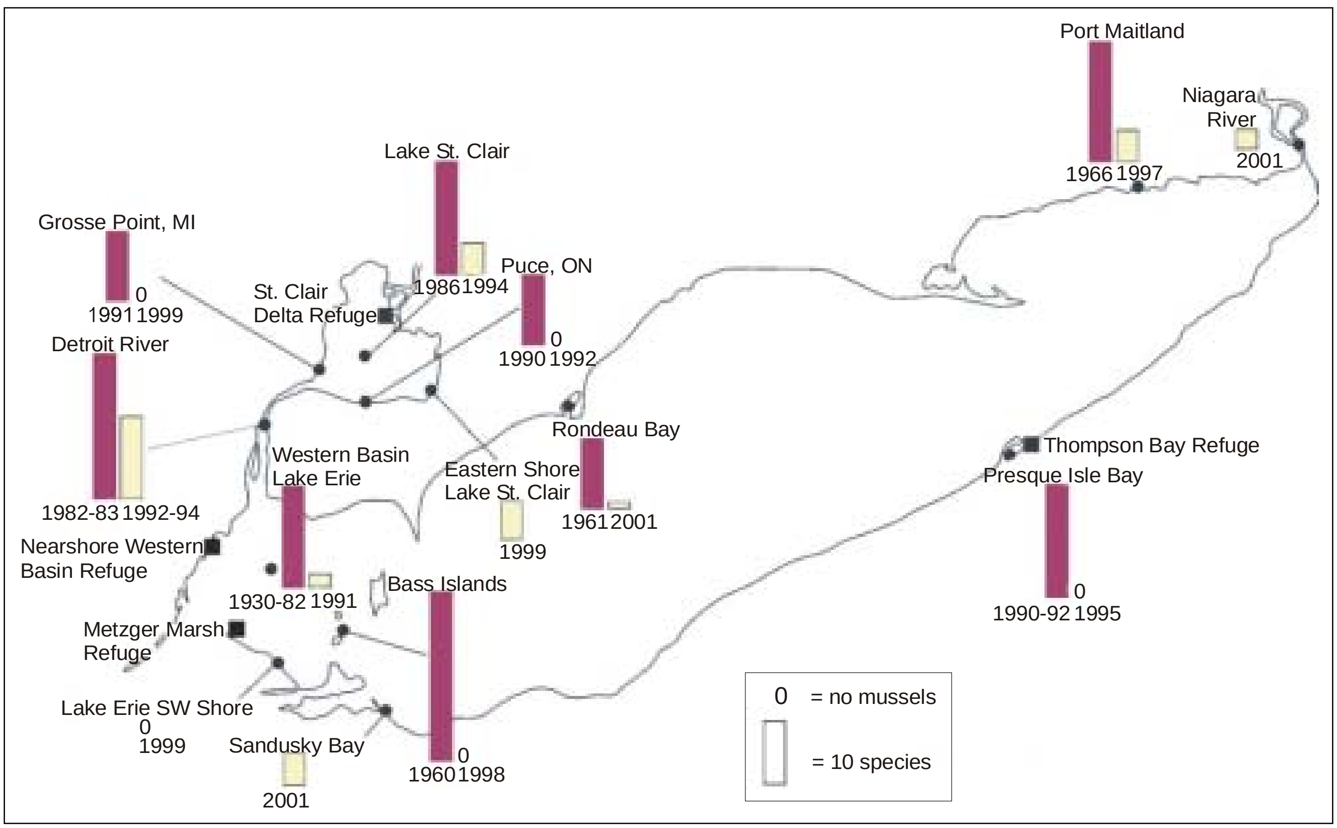

Figure 1. Numbers of freshwater mussel species found before and after the zebra mussel invasion at 13 sites in Lake Erie, Lake St. Clair, and the Niagara and Detroit Rivers (no “before” data available for 4 sites), and the locations of the four known refuge sites (Thompson Bay, Metzger Marsh, Nearshore Western Basin, and St. Clair Delta).

Source: Metcalfe-Smith, J.L., D.T. Zanatta, E.C. Masteller, H.L. Dunn, S.J. Nichols, P.J. Marangelo, and D.W. Schloesser, 2002

The introduction of the zebra mussel to the Great Lakes in the late 1980s has decimated unionid communities throughout the system. Zebra mussels attach to a mussel's shell, where they interfere with activities such as feeding, respiration and locomotion - effectively robbing it of the energy reserves needed for survival and reproduction. Lake Erie, Lake St. Clair and their connecting channels historically supported a rich mussel fauna of about 35 species. Unionid mussels were slowly declining in some areas even before the zebra mussel invasion. For example, densities in the western basin of Lake Erie decreased from 10 unionids/m2 in 1961 to 4/m2 in 1982, probably due to poor water quality. In contrast, the impact of the zebra mussel was swift and severe. Unionids were virtually extirpated from the offshore waters of western Lake Erie by 1990 and Lake St. Clair by 1994, with similar declines in the connecting channels and many nearshore habitats. The average number of unionid species found in these areas before the zebra mussel invasion was 18 (Fig. 1). After the invasion, 60% of surveyed sites had 3 or fewer species left alive, 40% of sites had none left, and abundance had declined by 90-95%.

It was feared that unionid mussels would be extirpated from Great Lakes waters by the zebra mussel. However, significant communities were recently discovered in several nearshore areas where zebra mussel infestation rates are low (Fig. 1).

All of the refuge sites discovered to date have two things in common: they are very shallow (<1-2 m deep), and they have a high degree of connectivity to the lake that ensures access to host fishes. These features appear to combine with other factors to discourage the settlement and survival of zebra mussels. Soft, silty substrates and high summer water temperatures in Metzger Marsh and Thompson Bay encourage unionids to burrow, which dislodges and suffocates attached zebra mussels. Unionids living in firm, sandy substrates at the Nearshore Western Basin site were nearly infestation-free. The few zebra mussels found were less than 2 years old, suggesting that they may be voluntarily releasing from unionids due to harsh conditions created by wave action, fluctuating water levels and ice scour. The St. Clair Delta site has both wave-washed sand flats and wetland areas with soft, muddy sediments. It is thought that the numbers of zebra mussel veligers reaching the area may vary from year to year, depending on wind and current direction and water levels.

Since zebra mussels have a planktonic larval stage (called a veliger) that requires an average of 20-30 days to develop into the benthic stage, rivers and streams have limited colonization potential and can provide natural refugia for unionids. However, regulated rivers, i.e., those with reservoirs, may not provide refugia. Reservoirs with retention times greater than 20-30 days will allow veligers to develop and settle, after which the impounded populations will seed downstream reaches on an annual basis. It is therefore vital to prevent the introduction of zebra mussels into reservoirs.

Future Pressures

Zebra mussel expansion is the main threat facing unionids in the Great Lakes drainage basin. Zebra mussels are now found in all of the Great Lakes and in many associated water bodies - including at least 180 inland lakes and river systems such as the Rideau River in Ontario. Other non-native species may also impact unionid survival through the reduction or redistribution of native fishes. Non-native fish species such as the Eurasian ruffe (Gymnocephalus cernuus) and round goby (Neogobius melanostomus) can completely displace native fish, thus causing the functional extirpation of local unionid populations.

Continuing changes in land-use (increasing urban sprawl, growth of factory farms, etc.), elevated use of herbicides to remove aquatic vegetation from lakes for recreational purposes, climate change and the associated lowering of water levels, and many other factors will continue to have an impact on unionid populations in the future.

Future Activities

The long-term goal is for unionid mussel populations to be stable and self-sustaining wherever possible throughout their historical range in the Great Lakes, including the connecting channels and tributaries. The most urgent activity is to prevent the further introduction of non-native species into the Great Lakes. A second critical activity is to prevent the further expansion of non-native species into the river systems and inland lakes of the region where they may seriously harm the remaining healthy populations of unionids that could be used to re-inoculate the Great Lakes themselves in the future.

Further Work Necessary

1. Compile and review all existing information on the status of freshwater mussels throughout the Great Lakes drainage basin. A complete analysis of trends over space and time are needed to properly assess the current health of the fauna.

2. To assist with the above exercise, and to guide future surveys, combine all data into a computerized, GIS-linked database (similar to the 6000-record Ontario database managed by the National Water Research Institute) accessible to all relevant jurisdictions.

3. Conduct additional surveys to fill data gaps, using standardized sampling designs and methods for optimum comparability of data. The Freshwater Mollusk Conservation Society is currently preparing a peer-reviewed, state-of-the art protocol that should be consulted for guidance. Populations of endangered and threatened species should be specifically targeted.

4. Document the locations of all existing refugia, both within and outside of the influence of zebra mussels, and protect them by all possible means from future disturbance.

5. Conduct research to determine the mechanisms responsible for survival of unionids in the various refuge sites, and use this knowledge to predict the locations of other refugia and to guide their management. Research in the St. Clair Delta refuge will begin in 2003. Ensure that the environmental requirements of unionids are taken into account in wetland restoration projects.

6. Actively pursue all avenues for educating the public about the plight of unionids in the Great Lakes, and legislating their protection. This includes ensuring that all species that should be listed are listed as quickly as possible.

7. Apply the principles of the National Strategy for the Conservation of Native Freshwater Mussels (The National Native Mussel Conservation Committee 1998) to the conservation and protection of the Great Lakes unionid fauna.

Acknowledgments

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Urban Density

SOLEC Indicator #7000 - Indicator Matrix

Note: At the time this report was prepared, the data from the 2000 U.S. Census had not yet been released below the county level for population density in the Lake Superior states. Still, it is felt that this indicator will benefit from mapping of data at the U.S. census block group and Canadian census subdivision or enumeration area level to show not only urban density but rural sprawl as well.

Assessment: Mixed Deteriorating (for Lake Superior basin)

Data are not system-wide.

Purpose

To assess the human population density in the Great Lakes basin, and to infer the degree of inefficient land use and urban sprawl for communities in the Great Lakes ecosystem.

Ecosystem Objective

Socioeconomic viability and sustainable development are generally accepted goals for society.

State of the Ecosystem

This information is presented to supplement the report on Urban Density in SOLEC 2000 Implementing Indicators (Draft for Review, November 2000).

Overall population for the 16 U.S. Lake Superior basin counties dropped 2.7 percent from 1930 to 2000 but increased 1.4 percent from 1990 to 2000. The U.S. population increased 128.4 and 13.1 percent during the same periods.

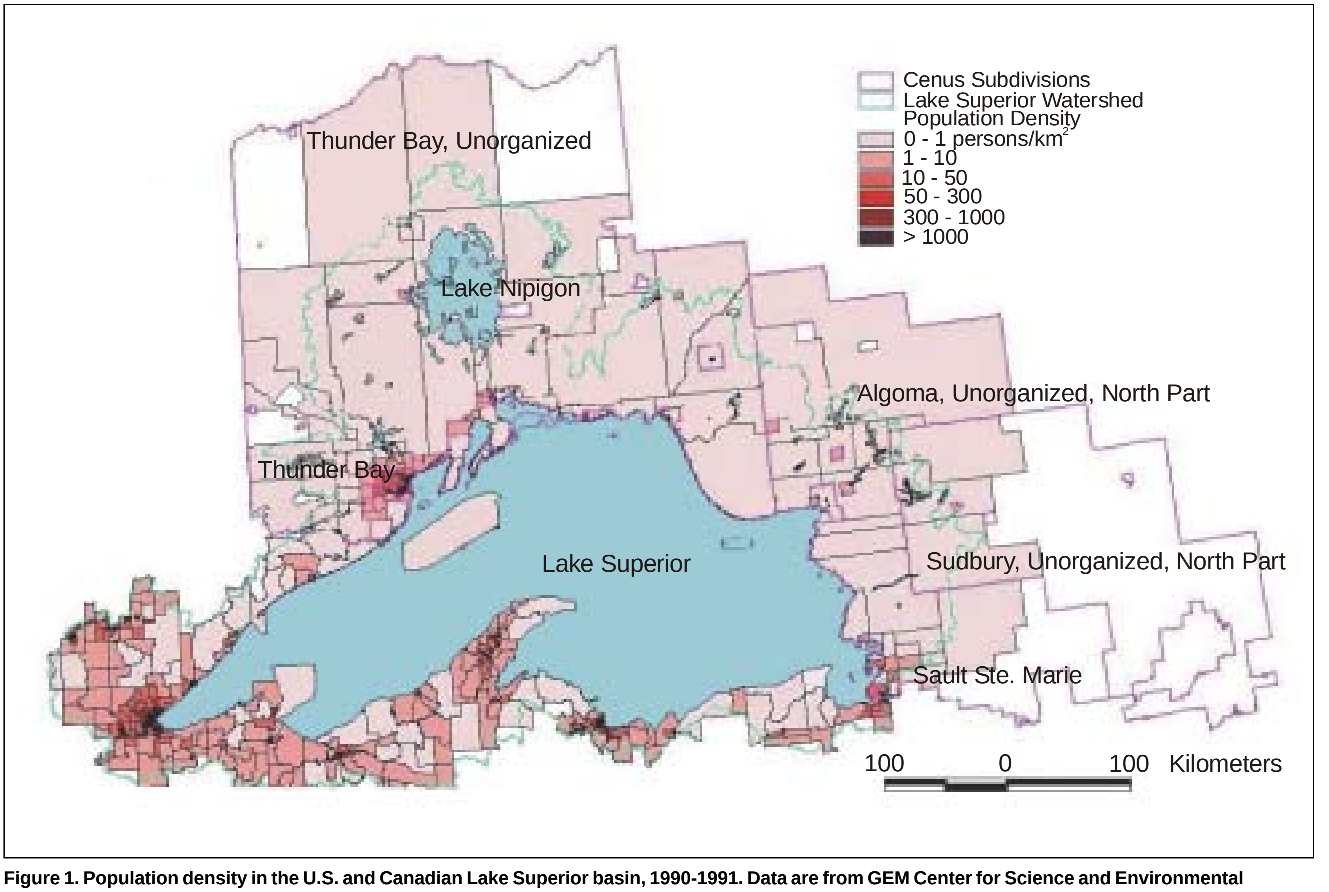

Figure 1. Population density in the U.S. and Canadian Lake Superior basin, 1990-1991. Data are from GEM Center for Science and Environmental Outreach, Michigan Technological University.

Source: U.S. Census TIGER 1990 census block group and Statistics Canada 1991 census enumeration area demographics; U.S. Geological Survey and Natural Resources Canada watershed boundaries

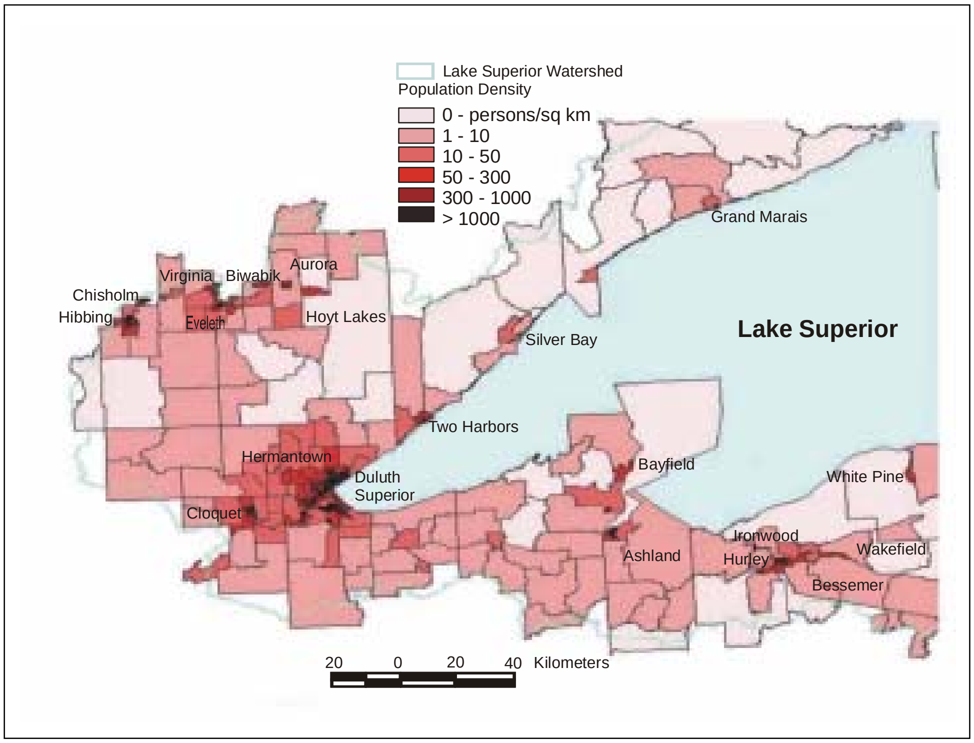

Figure 2. Population density by census block group, southwestern Lake Superior basin, 1990. Data are from GEM Center for Science and Environmental Outreach, Michigan Technological University.
Source: U.S. Census TIGER 1990 block groups and U.S. Geological Survey watershed boundaries

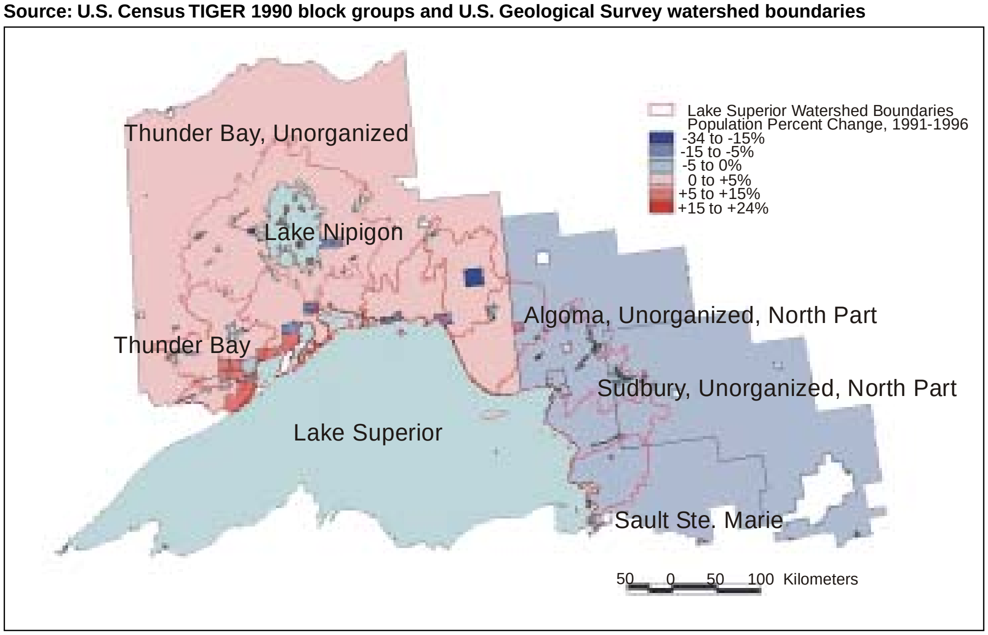

Figure 3. Percent change in population in the Ontario portion of the Lake Superior basin from 1991-1996. Data are from GEM Center for Science and Environmental Outreach, Michigan Technological University.
Source: Statistics Canada 1996 Census subdivision profiles for Ontario and Natural Resources Canada watershed boundaries

U.S. Census 1990 TIGER census block group data for the 540 census block groups mostly in the Lake Superior basin show a range of 0.1 to 5,640 persons/km^2, with a mean of 9.95, equivalent to 25.8 persons/mi^2 overall. The density calculated for the 16 counties mostly in the Lake Superior basin was slightly lower, at 20.1 persons/mi^2 (7.76 persons/km^2), compared to 70.3 persons/mi^2 (27.1 persons/km^2) for the U.S. as a whole.

In 2000, the density was virtually unchanged, at 20.4 persons/mi^2 (7.88 persons/km^2), compared to 79.6 persons/mi^2 (30.7 persons/km^2) for the U.S. as a whole and 61.8-175.0 persons/mi^2 (23.9-67.6 persons/km^2) for Michigan, Minnesota, and Wisconsin.

For the 31 participating Ontario census subdivisions that are part of the Lake Superior basin, data from Statistics Canada shows an overall population density of 1.29 and 1.28 persons/km^2 in 1991 and 1996, respectively. If the Algoma and Sudbury unorganized districts, which lie mostly outside the basin, are removed from the data set, density increases to 2.19 and 2.17 persons/km^2. Unlike the U.S. data, which are based on land area only, the Ontario data include land and water area, thus lowering the calculated population density. (For comparison, the population density for the U.S. part of the basin would be 8.72 persons/km^2 instead of 9.95 if water area were included.) The population density in 1991 ranged from 0.08 in Thunder Bay, Unorganized, to 1,393 persons/km^2 on the Pic Mobert South First Nations Reserve. The urban areas of Sault Ste. Marie and Thunder Bay had densities of 367.8 and 352.9, respectively. Figures 1 and 2 show persons/km^2 for the entire Lake Superior basin and a subset of the basin. Figure 3 shows the percentage change in population in the Ontario portion of the Basin from 1991 to 1996. The greatest population growth, in some cases 10 to 15 percent, generally occurred in townships adjacent to the City of Thunder Bay, which itself was essentially unchanged (-0.2 percent).

Future Pressures

Sprawl is increasingly becoming a problem in rural parts of the Great Lakes basin, placing a strain on infrastructure and consuming habitat in areas that tend to have healthier environments overall than those that remain in urban areas. This trend is expected to continue, which will exacerbate other problems, such as increased consumption of fossil fuels, longer commute times from residential to work areas, and fragmentation of habitat.

Future Activities

As noted in the SOLEC 2000 Urban Density indicator report, policies that encourage infill and brownfield redevelopment within urbanized areas will reduce sprawl. Comprehensive and land-use planning that incorporates “green” features, such as cluster development and greenway areas, will help to alleviate the pressure from development, but only if the plans are implemented through zoning, redevelopment incentives, or other means.

Further Work Necessary

Displaying U.S. and Canadian census population density on a GIS map will allow increasing sprawl to be documented over time in the Great Lakes basin on a variety of scales. For example, the maps included with this report show the entire Lake Superior basin and a closer view of the southwestern part of the basin.

Acknowledgments

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Economic Prosperity

SOLEC Indicator #7043 - Indicator Matrix

Assessment: Mixed (for Lake Superior Basin)
Data are not system-wide.

Purpose
To assess the unemployment rates within the Great Lakes basin, and, when used in association with other Societal indicators, to infer the capacity for society in the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem.

Ecosystem Objective
Human economic prosperity is a goal of all governments. Full employment (unemployment below 5% in western societies) is a goal for all economies and humans are part of the ecosystem.

State of the Ecosystem
This information is presented to supplement the report on Economic Prosperity in SOLEC 2000 Implementing Indicators (Draft for Review, November 2000). In 1975, 1980, 1985, 1990, 1995 and 2000 the civilian unemployment rate in the 16 U.S. Lake Superior basin counties averaged about 2.0 points above the U.S. average, and above the averages for their respective states, except occasionally Michigan (Figure 1). For example, the unemployment rate in the four Lake Superior basin counties in Minnesota was consistently higher than for Minnesota overall, 2.8 points on average but nearly double the Minnesota rate of 6.0 percent in 1985. Unemployment rates in individual counties ranged considerably, from 8.6 to 26.8 percent in 1985, for example.

In the 29 Ontario census subdivisions mostly within the Lake Superior watershed, the 1996 unemployment rate for the population 15 years and over was 11.5 percent. For the population 25 years and older, the unemployment rate was 9.1 percent. By location the rates ranged from 0 to 100 percent; the extremes, which occur in adjacent First Nations communities, appear to be the result of small populations and the 20 percent census sample. The most populated areas, Sault Ste. Marie and Thunder Bay, had unemployment rates for persons 25 years and older of 9.4 and 8.6 percent, respectively. Of areas with population greater than 200 in the labor force, the range was from 2.3 percent in Terrace Bay Township to 31.0 percent in Beardmore Township. Clearly, the goal of full employment (less than 5% unemployment) was not met in either the Canadian or the U.S. portions of the Lake Superior basin during the years examined.

Further Work Necessary
As noted in the SOLEC 2000 write-up, unemployment may not be sufficient as a sole measure for this indicator. Other information that is readily available

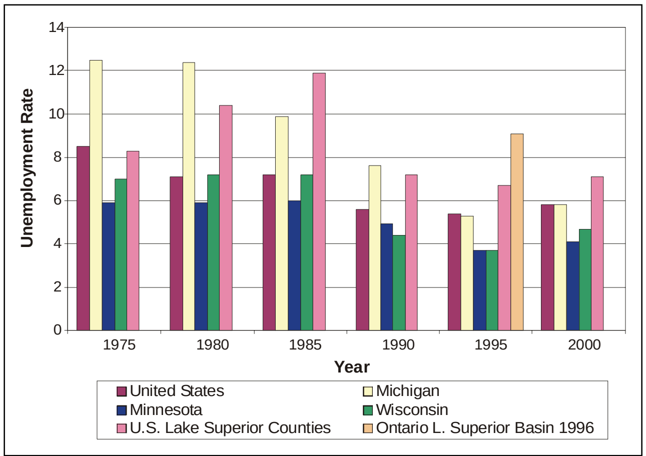

Figure 1. Unemployment rate in Michigan, Wisconsin, and the U.S. and Ontario Lake Superior basin, 1975-2000.
Source: U.S. Census Bureau and Statistics Canada

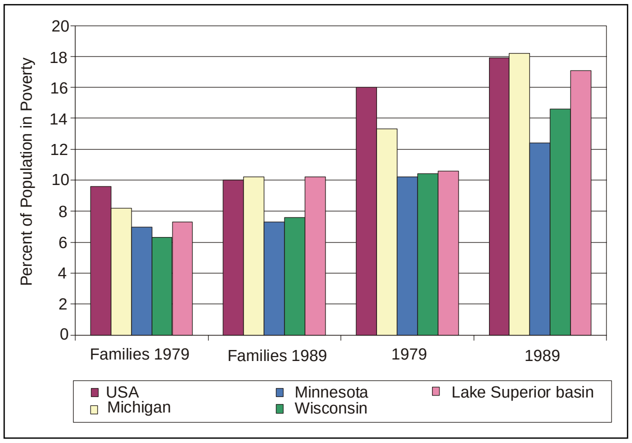

Figure 2. Individuals below poverty level in U.S. Great Lakes basin, 1979-1999, and families below poverty level in Ontario Great Lakes basin, 1999.
Source: U.S. Census Bureau

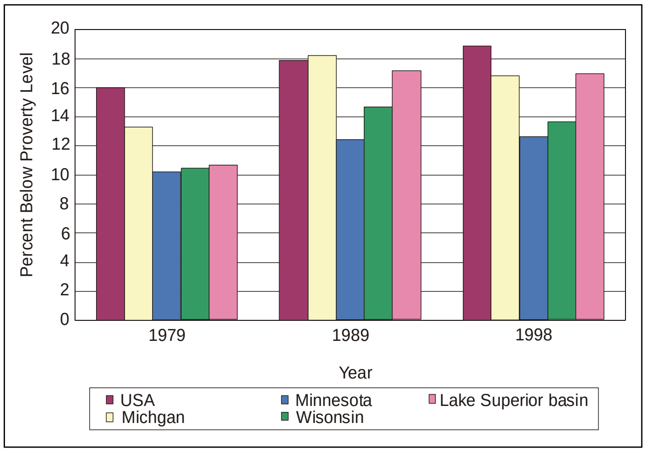

Figure 3. Children ages 18 or younger in poverty, 1979-1998, U.S. Lake Superior basin.
Source: U.S. Census Bureau

from the U.S. Census Bureau and Statistics Canada includes poverty statistics for the overall population, children under age 18, families, and persons age 65 and older. Two examples of trends in those measures are shown in Figures 2 and 3.

For persons of all ages within the U.S. Lake Superior basin for whom poverty status was established, 10.4 percent were below the poverty level in 1979. That figure had risen to 14.5 percent in 1989, a rate of increase higher than the states of Michigan, Minnesota, and Wisconsin and the U.S. overall over the same period. Poverty rates in all areas were lower in 1999, but the U.S. Lake Superior basin (and Ontario portion of the basin in 1996) was higher than any of the three states. The 1979 poverty rate for counties within the Lake Superior basin ranged from a low of 4.4 percent in Lake County, Minnesota, to a high of 17.0 percent in Houghton County, Michigan. In 1989 and 1999, those same counties again were the extremes.

Similarly, among children under age 18, poverty rates in the Great Lakes basin portions of the three states in 1979, 1989, and 1999 exceeded the rates of Minnesota and Wisconsin as a whole, though they remained below the U.S. rate. In a region where one-tenth to one-sixth of the population lives in poverty, environmental sustainability is likely to be perceived by many as less important than economic development.

Acknowledgments
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Area, Quality, and Protection of Great Lakes Islands

SOLEC Indicator #8129 (islands) - Indicator Matrix

Assessment: Not Assessed
Indicator is under development. Data are not available.

Purpose
This indicator assesses the status islands, of one of the 12 special lakeshore communities identified within the nearshore terrestrial area. There are over thirty thousand islands in the Great Lakes. The islands range in size from no bigger than a large boulder to the world's largest freshwater island, Manitoulin, and often form chains of islands known as archipelagos. Though not well known, the Great Lakes contain the world's largest freshwater island system, and are globally significant in terms of their biological diversity. Despite this, the state of our knowledge about them is quite poor.

Ecosystem Objective
To assess the changes in area and quality of Great Lakes islands individually, and as an ecologically important system; to infer the success of management activities; and to help focus future conservation efforts associated with the protection of some of the most ecologically significant habitats in the Great Lakes.

State of the Ecosystem
By their very nature, islands are vulnerable and sensitive to change. As water levels rise and fall, islands are exposed to the forces of erosion and accretion. Islands are exposed to weather events due to their 360-degree exposure to the elements across the open water. Isolated for perhaps tens of thousands of years from the mainland, islands in the

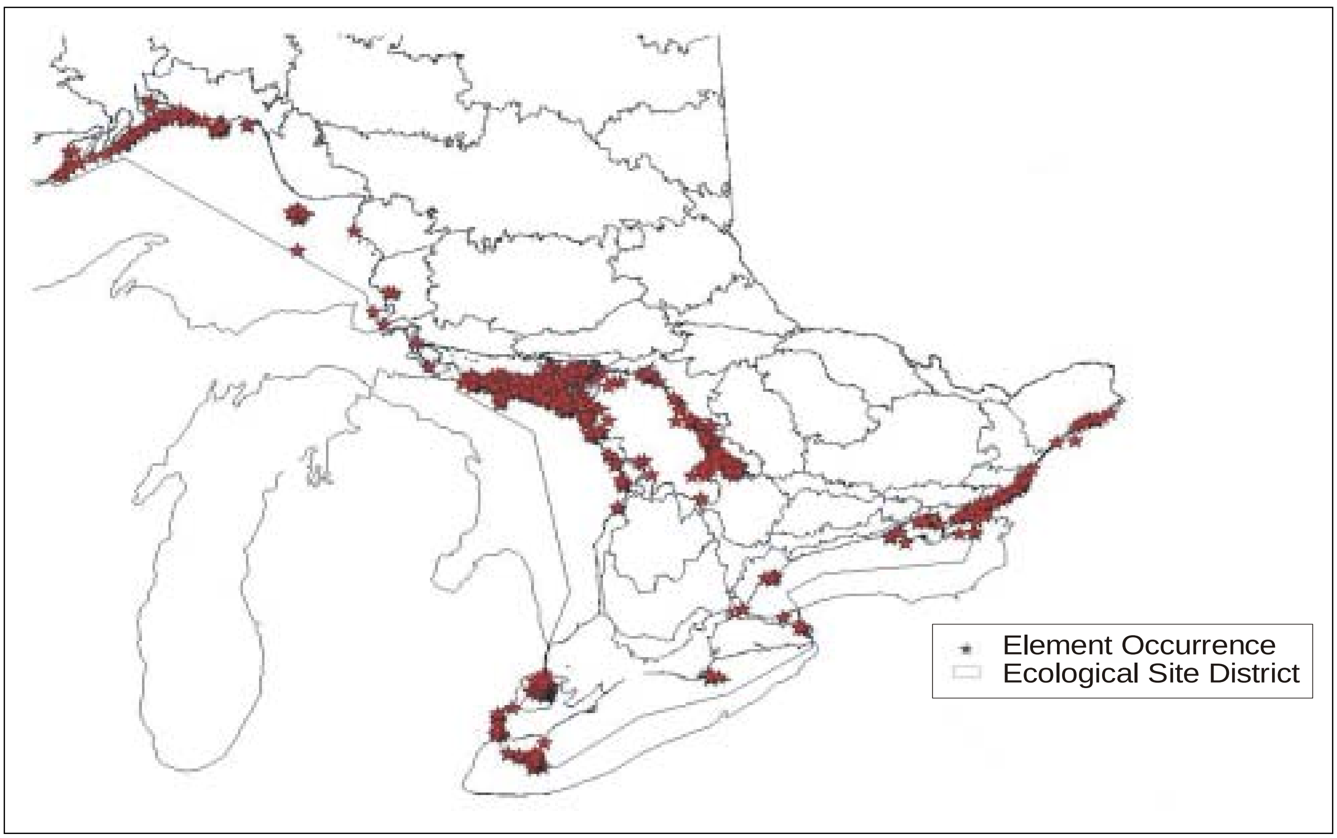

Figure 1. Distribution of Ontario's provincially rare species and vegetation communities on islands in the Great Lakes.
Source: Ontario Natural Heritage Information Centre, March 2003

past rarely gained new species, and their resident species often evolved into endemics, that differed from mainland varieties. This means that islands are especially vulnerable to the introduction of non-native species, among other things.

Some of the Great Lakes islands are among the last remaining wildlands on Earth. Islands could be considered as a single irreplaceable resource and protected as a whole if the high value of this natural heritage is to be maintained. For example, Michigan's Great Lakes islands contain one-tenth of the state's threatened, endangered, or rare species while representing only one-hundredth of the land area. All of Michigan's threatened, endangered, or rare coastal species occur at least in part on its islands. The natural features of particular importance are the colonial waterbirds, neartic-neotropical migrant songbirds, endemic plants, endangered species, fish spawning and nursery use of associated shoals and reefs and other aquatic habitat, marshes, alvars, coastal barrier systems, sheltered embayments, nearshore bedrock mosaic, and sand dunes.

Future Pressures

By their very nature, islands are more sensitive to human influence than the mainland and need special protection to conserve their natural values. Proposals to develop islands are increasing. This is occurring before we have the scientific information and processes, or knowledge regarding use in place to evaluate, prioritize, and make appropriate natural resource decisions. Island stressors include: development, invasive species, shoreline modification, marina development, agriculture and forestry practices, recreational use, navigation/shipping practices, wastewater discharge, mining practices, drainage or diversion systems, overpopulation of certain species such as deer and cormorants, industrial discharge, development of roads or utilities, and disruption of natural disturbance regimes.

Future Activities

The Great Lakes islands provide a unique opportunity to protect a resource of global importance because many islands still remain intact. The U.S. Fish and Wildlife Service's Great Lake Basin Ecosystem Team (GLBET)-has taken on the charge of providing leadership to coordinate and improve the protection and management of the islands of the Great Lakes. The GLBET island initiative includes the coordination and compilation of island geospatial data and information, developing standardized survey/monitoring protocols, holding an island workshop in the fall of 2002 to incorporate input from partners for addressing the SOLEC Island Indicator needs, and completion of a Great Lakes Islands Conservation Strategic Plan.

Recent and ongoing Great Lakes island conservation initiatives include the newly established International Detroit River Wildlife Refuge (the first ever International Wildlife Refuge), the proposed restoration of the Green Bay Cat Island Chain, and the binational Western Lake Erie Islands Conservation Planning Project.

The information conveyed by this indicator will help to focus attention and management efforts to best conserve these unique and globally significant Great Lakes resources.

Acknowledgments

Richard H. Greenwood, U.S. Fish and Wildlife Service, Great Lakes Basin Ecosystem Team Leader; and Liaison to U.S. Environmental Protection Agency-Great Lakes National Program Office, Chicago, IL.

Sources

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1.3 PRESSURE INDICATOR REPORTS-PART 1

SUMMARY OF PRESSURE INDICATORS-PART 1

The overall assessment for the Pressure indicators is incomplete. Part One of this Assessment presents the indicators for which we have the most comprehensive and current basin-wide information. Data presented in Part Two of this report represent indicators for which information is not available year to year or are not basin-wide across jurisdictions. Within the Great Lakes indicator suite, 38 have yet to be reported, or require further development. In a few cases, indicator reports have been included that were prepared for SOLEC 2000, but that were not updated for SOLEC 2002. The information about those indicators is believed to be still valid, and therefore appropriate to be considered in the assessment of the Great Lakes. In other cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

Indicator Name	Assessment in 2000	Assessement in 2002
Spawning-Phase Sea Lamprey	Mixed	Mixed, improving
Phosphorus Concentrations and Loadings	Mixed	Mixed
Contaminants in Colonial Nesting Waterbirds	Good	Mixed, improving
Atmospheric Deposition and Toxic Chemicals	Mixed, improving	Mixed
Contaminants in Edible Fish Tissue	Mixed, improving	Mixed, improving
Air Quality	Mixed	Mixed
Ice Duration on the Great Lakes	No Report	Mixed, deteriorating (with respect to climate change)
Extent of Hardened Shoreline	Mixed, deteriorating	Mixed, deteriorating
Contaminants Affecting Productivity of Bald Eagles	Mixed, improving	Mixed, improving
Acid Rain	Mixed	Mixed, improving
Non-native Species introduced into the Great Lakes	Poor	Poor

Green represents an improvement of the indicator assessment from 2000.
Red represents deterioration of the indicator assessment from 2000.
Black represents no change in the indicator assessment from 2000, or where no previous assessment exists.

Sea Lamprey

Indicator ID #18 - Indicator Matrix

Assessment: Mixed Improving

Purpose
Estimates of the abundance of sea lamprey are presented as an indicator of the status of this invasive species and of the damage it causes to the fish communities and aquatic ecosystems of the Great Lakes. Populations of the native top predator, lake trout, and other fishes are negatively affected by mortality caused by sea lamprey.

Ecosystem Objective
The 1955 Convention of Great Lakes Fisheries created the Great Lakes Fishery Commission (GLFC) "*to formulate and implement a comprehensive program for the purpose of eradicating or minimizing the sea lamprey populations in the Convention area*" (GLFC 1955). Under the Joint Strategic Plan for Great Lakes Fisheries, lake committees, consisting of all fishery management agencies, have established Fish Community Objectives (FCOs) for each of the lakes. These FCOs cite the need for sea lamprey control to support objectives for the fish community, in particular, objectives for lake trout, the native top predator. The FCOs include endpoints for sea lamprey of varying specificity:

Superior (Bushian 1990) - *50% reduction in parasitic-phase sea lamprey abundance by 2000, and a 90% reduction by 2010*;
Michigan (Eshenroder *et al*. 1995) - *Suppress the sea lamprey to allow the achievement of other fish-community objectives*;
Huron (DesJardine *et al*. 1995) - *75% reduction in parasitic sea lamprey by the year 2000 and a 90% reduction by the year 2010 from present levels*;
Erie (1999 draft) - *Sea lamprey are a pest species requiring control;*
Ontario (Stewart *et al*. 1999) - *Suppress sea lamprey to early-1990s levels, and maintaining marking rates at <0.02 marks/lake trout.*

State of the Ecosystem
The first complete round of stream treatments with the lampricide TFM, as early as 1960 in Lake Superior, successfully suppressed sea lamprey to less than 10% of their pre-control abundance in all of the Great Lakes.

Mark and recapture estimates of the abundance of sea lamprey migrating up rivers to spawn is used as a surrogate of the abundance of parasites feeding in the lakes during the previous year. Estimates of individual spawning runs in trappable streams are used to estimate lake-wide abundance using a new regression model that relates run size to stream characteristics (Mullett *et al. in press*). Sea lamprey spend one year in the lake after metamorphosing, so this indicator has a two-year lag in demonstrating the effects of control efforts. Figure 1 presents these lake-wide estimates since 1980.

Lake Superior: During the past 20 years, populations have fluctuated but remain at levels less than 10% of peak abundance. The FCO for sea lamprey was met in 1994 and 1995, but abundance has increased since 1995 (Heinrich *et al. in press*). Recent increased abundance estimates have raised concern in all waters. Marking rates have shown the same pattern of increase especially in some areas of Canadian waters. Survival objectives for lake trout continue to be met but could be threatened if increases were to continue. Stream treatments were increased during 2001 and 2002 in response to the observed trends. The effects of these additional stream treatments will be first observed in the spawning-run estimates during 2003.

Lake Michigan: The population of sea lamprey has shown a continuing, slow trend upward. Marking rates on lake trout have shown a similar trend upward in recent years, but the general FCOs for survival are being met (Lavis *et al. in press*). Increases in abundance during the 1990s had been attributed to the St. Marys River. The continuing trend in recent years suggests sources of sea lamprey in Lake Michigan itself rather than from Lake Huron as previously believed. Stream treatments were increased in 2001 and 2002 including treatment of newly discovered populations in lentic areas.

Lake Huron: Following the success of the first full round of stream treatments during the late 1960s, sea lamprey populations were suppressed to low levels (<10%) through the 1970s (Morse *et al. in press*). During the early 1980s, populations increased in Lake Huron, particularly the north. This increase continued and peaked in 1993. Through the 1990s Lake Huron contained more sea lamprey than all the other lakes combined. FCOs were not being achieved. The Lake

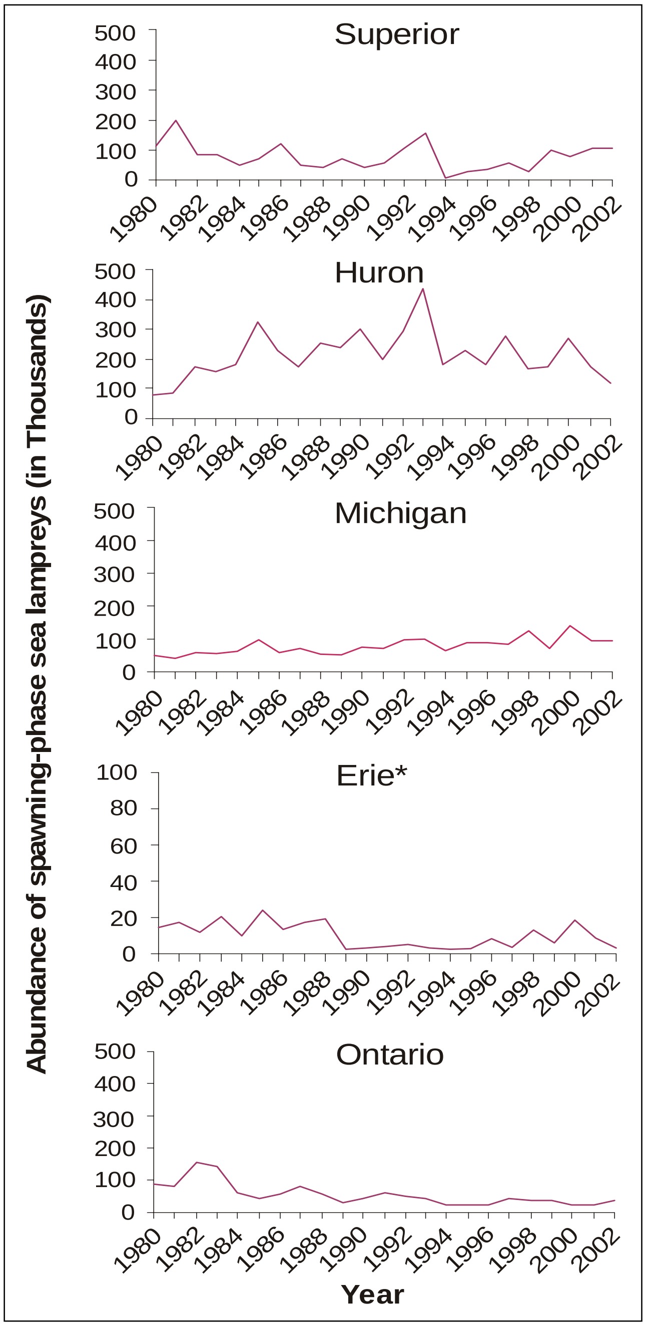

Figure 1. Figure 60. Total annual abundance of sea lamprey estimated during the spawning migration. *Note the scale for Lake Erie is 1/5th the scale size when compared to the other Lakes.
Source: Gavin Christie and Jeffrey Slade, Great Lakes Fishery Commission, Rodney McDonald, Department of Fisheries and Oceans Canada, and Katherine Mullett, U.S. Fish and Wildlife Service

Huron Committee had to abandon its lake trout restoration objective in the northern portion of the lake during 1995 because so few lake trout were surviving attacks by sea lamprey to survive to maturity. The St. Marys River was identified as the source of this increase. The size of this connecting channel made traditional treatment with the lampricide TFM impractical. A new integrated control strategy including targeted application of a new formulation of a bottom-release lampricide, enhanced trapping of spawning animals, and sterile-male release was initiated in 1997 (Schleen *et al. in press*). As predicted, a decline in spawning-phase abundance was observed during 2001 as a result of the completion of the first full round of lampricide spot treatments during 1999. While this decline continued through 2002, the population shows considerable variation and the full effect of the control program will not be observed for another 2-4 years (Adams *et al. in press*). Wounding rates and mortality estimates for lake trout have also declined during the last two years.

Lake Erie: Following the completion of the first full round of stream treatments in 1987, sea lamprey populations collapsed (Sullivan *et al. in press*). Marking rates on lake trout declined and survival increased to levels sufficient to meet the rehabilitation objectives in the eastern basin. However, during the mid-1990s, sea lamprey abundance has increased to levels that threatened the lake trout restoration effort. A major assessment effort during 1998 indicated that the source of this increase was several streams in which treatments had been deferred due to low water flows or concerns for non-target organisms. These critical streams were treated during 1999 and 2000. Sea lamprey abundance was observed to decline in 2001 and then more dramatically in 2002. While more years of low abundance will be required for full confirmation, these decreases can be interpreted as successful. Wounding rates on lake trout have also declined in the lake.

Lake Ontario: Abundance of spawning-phase sea lamprey has continued to decline to low levels through the 1990s (Larson *et al. in press*). The abundance of sea lamprey has remained stable during 2000-2002. The FCOs for sea lamprey abundance continues to be achieved, but lake trout marking rates have exceeded the target if only slightly during the last two years.

Future Pressures
Since parasitic-phase sea lamprey are at the top of the aquatic food chain and inflict high mortality on large piscivores, population control is essential for healthy fish communities. The potential for sea lamprey to colonize new locations is increased with improved water quality and removal of dams. Increasing abundance in Lake Erie demonstrates how short lapses in control can result in rapid increases of abundance and that continued effective stream treatments are necessary to overcome the reproductive potential of this invading species.

As fish communities recover from the effects of sea lamprey predation or overfishing, there is evidence that the survival of parasitic sea lamprey may increase due to prey availability. Better survival means that there are more residual sea lamprey to cause harm. Significant additional control efforts, like those on the St. Marys River, may be necessary to maintain suppression.

The GLFC has a goal of reducing reliance on lampricides and increasing efforts to integrate other control techniques, such as the sterile-male-release-technique or the installation of barriers to stop the upstream migration of adults. Pheromones that affect migration and mating have been discovered and offer exciting potential as new alternative controls. The use of alternative controls is consistent with sound practices of integrated pest management, but can put additional pressures on the ecosystem such as limiting the passage of fish upstream of barriers. Care must be taken in applying new alternatives or in reducing lampricide use to not allow sea lamprey abundance to increase.

Future Actions
The GLFC has increased stream treatments and lampricide applications in response to increasing abundances. The GLFC continues to focus on research and development of alternative control strategies. Computer models, driven by empirical data, are being used to best allocate treatment resources, and research is being conducted to better understand and manage in the variability in sea lamprey populations.

Further Work Necessary
Targeted increases in lampricide treatments are predicted to reduce sea lamprey to acceptable levels. The effects of increased treatments will be observed in this indicator beginning in 2003. Discrepancies among estimates of different life-history stages need to be resolved. Efforts to identify all sources of sea lamprey need to continue. In addition, research to better understand lamprey/prey interactions, the population dynamics of sea lamprey that survive control actions, and refinement of alternative control methods are all key to maintaining sea lamprey at tolerable levels.

Acknowledgments
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Phosphorus Concentrations and Loadings

SOLEC Indicator #111 - Indicator Matrix

Assessment: Mixed

Purpose
This indicator assesses total phosphorus levels in the Great Lakes, and is used to support the evaluation of trophic status and food web dynamics in the Great Lakes. Phosphorus is an essential element for all organisms and is often the limiting factor for aquatic plant growth in the Great Lakes. Although phosphorus occurs naturally, the historical problems caused by elevated levels have originated from man-made sources. Detergents, sewage treatment plant effluent, agricultural and industrial sources have historically introduced large amounts into the Lakes.

Ecosystem Objective
The goals of phosphorus control are to maintain an oligotrophic state in Lakes Superior, Huron and Michigan; to maintain algal biomass below that of a nuisance condition in Lakes Erie and Ontario; and to eliminate algal nuisance growth in bays and in other areas wherever they occur (GLWQA Annex 3). Maximum annual phosphorus loadings to the Great Lakes that would allow achievement of these objectives are listed in the GLWQA. The expected concentrations of total phosphorus in the open waters of the Great Lakes, if the maximum annual loads are maintained, are listed in the following table:

State of the Ecosystem
Strong efforts begun in the 1970s to reduce phosphorus loadings have been successful in maintaining or reducing nutrient concentrations in the Lakes, although high concentrations still occur locally in some embayments and harbors. Phosphorus loads have decreased in part due to changes in agricultural practices (e.g., conservation tillage and integrated crop management), promotion of phosphorus-free detergents, and improvements made to sewage treatment plants and sewer systems. Average concentrations in the open waters of Lakes Superior, Michigan, Huron, and Ontario are at or below expected levels. Concentrations in the three basins of Lake Erie fluctuate from year to year (Figure 1) and frequently exceed target concentrations. In Lakes Ontario and Huron, although most offshore waters meet the desired guideline, some offshore and nearshore areas and embayments experience elevated levels which could promote nuisance algae growths such as the attached green algae, Cladophora.

Summarizing the information into an indicator is too subjective until the specifics regarding the metric have been defined.

Future Pressures
Even if current phosphorus controls are maintained, additional loadings can be expected. Increasing numbers of people living along the Lakes will exert increasing demands on existing sewage treatment facilities, possibly contributing to increasing phosphorus loads.

Future Actions
Because of its key role in productivity and food web dynamics of the Great Lakes, phosphorus concentrations continue to be watched by environmental and fishery agencies. Future activities that are likely to be needed include: 1) Assess the capacity and operation of existing sewage treatment plants in the context of increasing human populations being served. Additional upgrades in construction or operations may be required; 2) Conduct sufficient tributary monitoring to support the calculation of annual loadings of phosphorus to each Great Lake by source category (i.e., sewage treatment plans, tributaries, etc.). If the phosphorus

Lake	Phosphorus Guideline (µg/L)
Superior	5
Huron	5
Michigan	7
Erie - Western Basin	15
Erie - Central Basin	10
Erie - Eastern Basin	10
Ontario	10

Figure 1. Phosphorus guidelines for the Great Lakes.
Source: Great Lakes Water Quality Agreement, 1978

concentrations remain stable at or below the maximum target levels for most of the Lakes, loadings information might be useful, but not critical.

Further Work Necessary
The analysis of phosphorus concentrations in the Great Lakes is ongoing and reliable. However, a coordinated enhanced monitoring program is required with agreement on specifics such as analytical and field methodologies, sampling locations, inclusion of nearshore and embayment sites, determination of the indicator metric and the index. The data needed to support loadings calculations have not been collected since 1991 in all lakes except Erie, which has loadings information up to 2000. Efforts to do so should be reinstated for at least Lake Erie. Otherwise, the loadings component of this SOLEC indicator will remain unreported, and changes in the different sources of phosphorus to the Lakes may go undetected.

Acknowledgments

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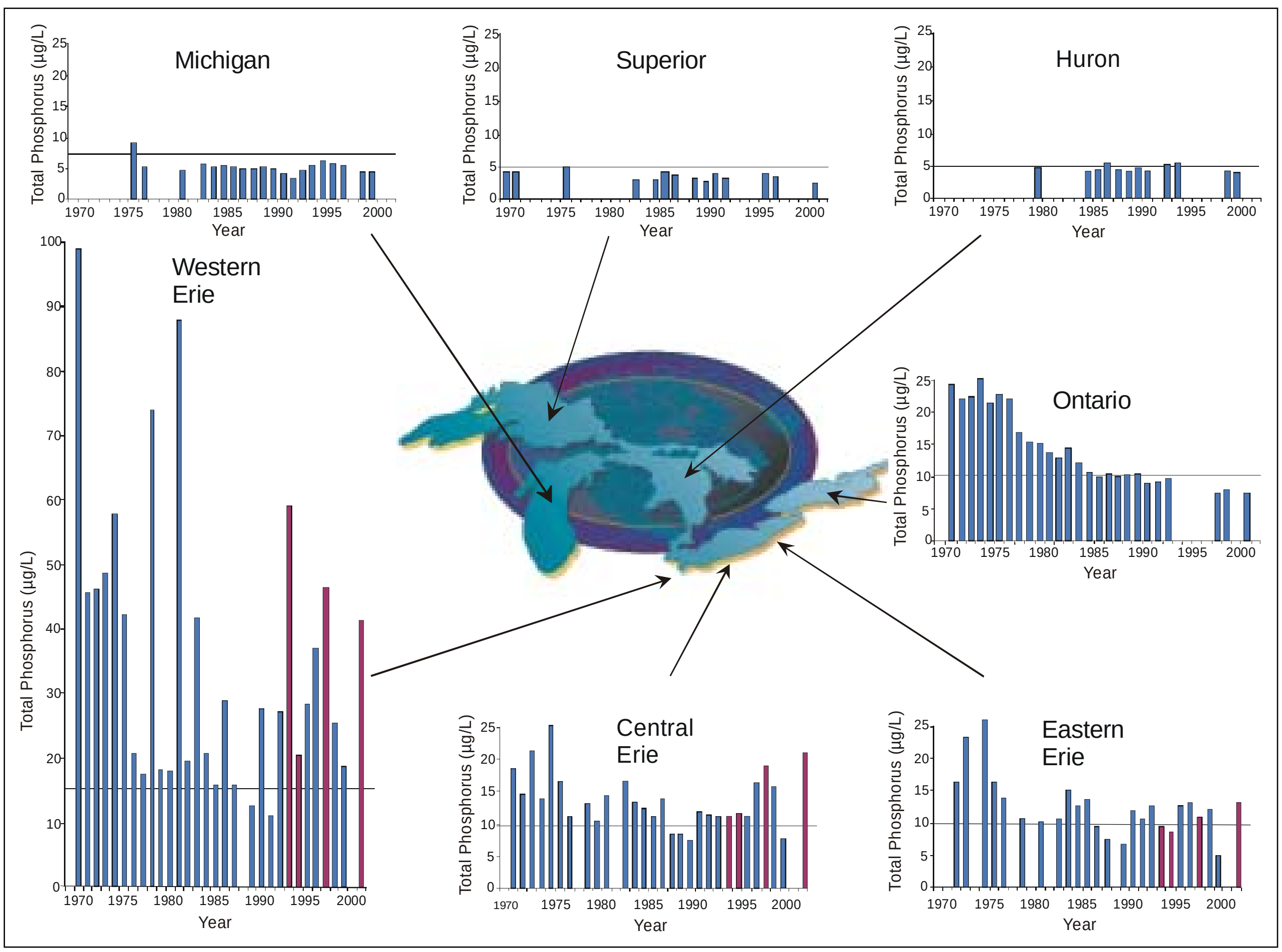

Figure 2. Total phosphorus trends in the Great Lakes 1971-2002 (Spring, Open Lake, Surface). Blank indicates no sampling. Horizontal line on each graphic represents the phosphorus guideline as listed in the Great Lakes Water Quality Agreement for each Lake. Burgundy bar graphs represent Environment Canada data. Blue bar graphs represent U.S. Environmental Protection Agency data.
Source: Environmental Conservation Branch, Environment Canada and U.S. Environmental Protection Agency

Contaminants in Colonial Nesting Waterbirds

SOLEC Indicator #115 - Indicator Matrix

Assessment: Mixed Improving

Purpose

This indicator will assess current chemical concentrations and trends as well as ecological and physiological endpoints in representative colonial waterbirds (gulls, terns, cormorants and/or herons) on the Great Lakes. These features will be used to infer and measure the impact of contaminants on the health, i.e. the physiology and breeding characteristics, of the waterbird populations. This indicator is important because colonial waterbirds are one of the top aquatic food web predators in the Great Lakes ecosystem and they are very visible and well known to the public. They bioaccumulate contaminants to the greatest concentration of any trophic level organism and they breed on all the Great Lakes. Thus, they are a very cost efficient monitoring system and allow easy inter-lake comparisons. The current Herring Gull Egg Monitoring program is the longest continuous-running annual wildlife contaminants monitoring program in the world (1974-present). It determines concentrations of up to 20 organochlorines, 65 PCB congeners and 53 PCDD and PCDF congeners (Braune *et al*. In review).

Ecosystem Objective

One of the objectives of monitoring colonial waterbirds on the Great Lakes is to discover the point when there is no difference in contaminant levels and related biological endpoints between birds on and off the Great Lakes. When colonial waterbirds from the Great Lakes do not differ in chemical and biological parameters from birds off the Great Lakes, e.g. birds in northern Saskatchewan or the Maritimes, then our clean-up objective will have been reached. Other objectives include determining temporal and spatial trends in contaminant levels in colonial waterbirds and detecting changes in their population levels on the Great Lakes.

State of the Ecosystem

The Herring Gull Egg Monitoring Program has provided researchers and managers with a powerful tool (a 28 year database) to evaluate changes in contaminant concentrations in Great Lakes wildlife (Figure 1). The extreme longevity of the egg database makes it possible to calculate temporal trends in contaminant concentrations in wildlife and to look for significant changes within those trends. Contaminant "hot spots" for wildlife have been identified by testing for spatial patterns among the 15 Annual Monitor Colonies (Weseloh *et al*. 1990, Ewins *et al*. 1992) (Figure 2). The database shows that most contaminants in gull eggs have declined a minimum of 50% and many have declined more than 90% since the program began in 1974. In 2002, PCB, HCB, DDE, HE, dieldrin, mirex and 2,3,7,8-TCDD levels measured in eggs from the Annual Monitor Colonies (N=105) were analysed for temporal trends. Analysis showed that in 72% of cases (76/105), the contaminants were decreasing as fast as or faster in recent years than they had in the past. In 22% of cases (23/105), contaminants were decreasing slower than they had in the past. (Calculated from Bishop *et al*. 1992, Pettit *et al*. 1994, Pekarik *et al*. 1998 and Jermyn *et al*. 2003, as per Pekarik and Weseloh , 1998). PCBs were the compound showing the most frequent reduction in their rate of decline.

A comparison of 1999 and 2001 levels of the seven contaminants at the 15 sites (N=105) showed that in 78% of the cases (82/105), levels decreased since 1999. More than half of these comparisons (43/82) showed declines from 1999 to 2000 and from 2000 to 2001. Dieldrin and Granite Island (Lake Superior) showed the greatest number of repeatedly declining

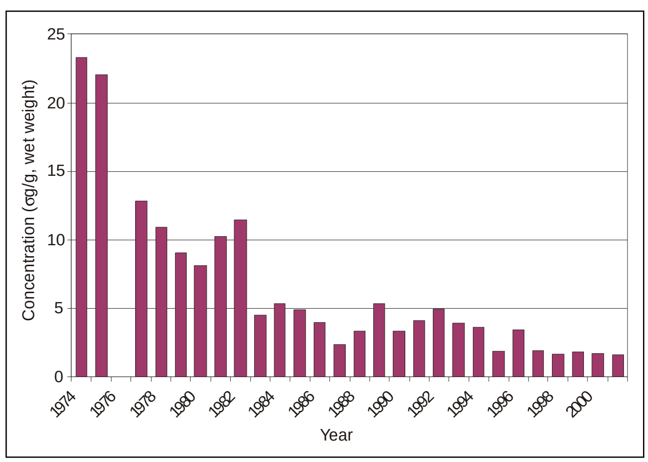

Figure 1. Temporal trends in DDE in herring gull eggs from Toronto Harbour, 1974-2002.
Source: Bishop *et al*., 1992; Pettit *et al*., 1994; Pekarik *et al*., 1998 and Jermyn *et al*., 2003

comparisons. In 20% of the cases (21/105), levels increased since 1999. In 38% of these cases (8/21), levels increased from 1999 to 2000 and from 2000 to 2001. 2,3,7,8-TCDD and Channel-Shelter Island (Saginaw Bay, Lake Huron) showed the greatest number of repeatedly increasing comparisons. Two percent of the cases (2/105), both involving HCB, showed no change in levels from 1999 to 2001 (Jermyn *et al*. 2003).

Spatially, in 2001, gull eggs from Lake Ontario and the St. Lawrence River continued to have the greatest levels of mirex. The greatest dioxin (2,3,7,8-TCDD) levels were found at Saginaw Bay (Lake Huron) followed by the St. Lawrence-Lake Ontario-Niagara River corridor. Sites on Lake Michigan had the greatest levels of dieldrin and heptachlor epoxide. Eggs from Saginaw Bay and Lake Michigan had the greatest levels of DDE. HCB was found in the greatest amounts at Saginaw Bay and the Niagara River. Eggs from Saginaw Bay and the Detroit River-Western Lake Erie area had the greatest levels of PCBs (Jermyn *et al*. 2003).

In terms of gross ecological effects of contaminants on colonial waterbirds, e.g. eggshell thinning, failed reproductive success and population declines, most species seem to have recovered. Populations of most species have increased over the past 25-30 years (Blokpoel and Tessier 1993, 1996, 1997, 1998; Austin *et al*. 1996; Scharf and Shugart 1998, Cuthbert *et al*. 2001;

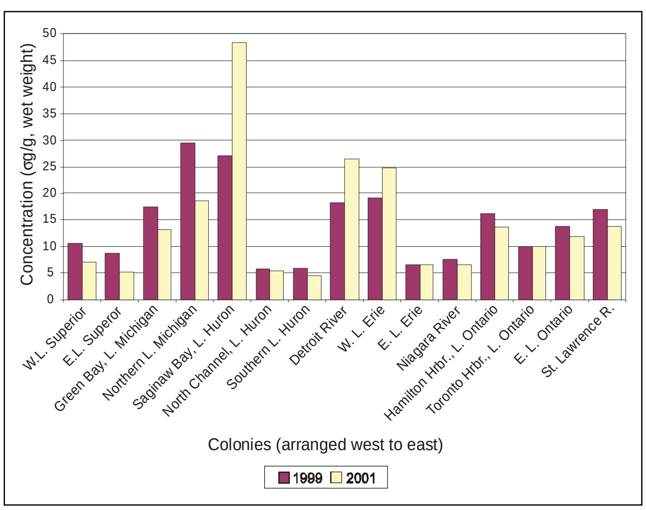

Figure 2. Changes in spatial patterns of PCB 1:1 levels in herring gull eggs from the Annual Monitor Colonies, 1999 and 2001.
Source: Jermyn *et al.*, 2003

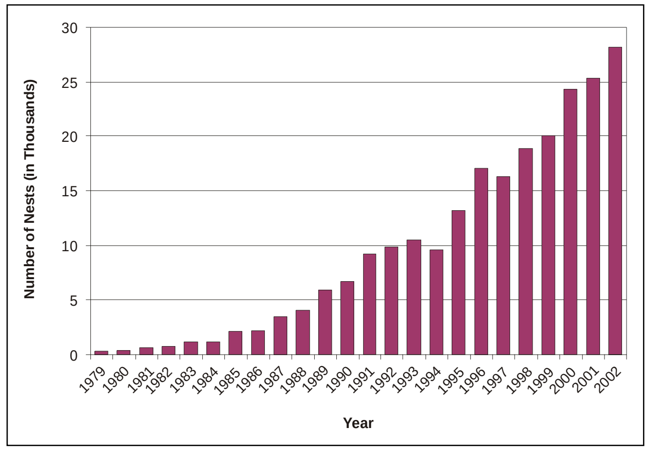

Figure 3. Nest Numbers (number of breeding pairs) of Double-crested Cormorants on Lake Ontario, 1979-2002.
Source: Price and D.V. Weseloh, 1986; Havelka and D.V. Weseloh, 2003

Weseloh *et al*. 2002; Morris *et al*. in review, CWS unpubl. data). Interestingly, Double-crested Cormorants, whose population levels have increased more than 400-fold (Figure 3), have been shown to be still exhibiting some eggshell thinning (Custer *et al*. 1999). Although the gross effects appear to have subsided, there are many other subtle, mostly physiological and genetic endpoints that are being measured now that were not measured in earlier years. For example, porphyrins, retinoids and germline minisatellite DNA mutations have been found to correlate with contaminant levels in Herring Gulls (Fox et al. 1988, Fox 1993, Grasman et al. 1996, Yauk and Quinn 1999). However, the conclusion is that the colonial waterbirds of the Great Lakes are much healthier now than they were during the 1970s.

Future Pressures
Future pressures for this indicator include all sources of contaminants which reach the Great Lakes. This includes those sources that are already well known, e.g. re-suspension of sediments, as in western Lake Erie, and atmospheric inputs, such as PCBs in Lake Superior, as well as lesser known ones, such as underground leaks from landfill sites.

Future Activities
The annual collection and analysis of Herring Gull eggs from 15 sites on both sides of the Great Lakes and the assessment of that species' reproductive success is a permanent part of the Great Lakes

surveillance activities; likewise, so is the regular monitoring of population levels of most of the colonial waterbird species. The plan is to continue these procedures. Research work on improving and expanding the Herring Gull Egg Monitoring program is done on a more opportunistic, less predictable basis (see below, Further Work Necessary).

Further Work Necessary

We have learned much about interpreting the Herring Gull egg contaminants data from associated research studies. However, much of this work is done on an opportunistic basis, when funds are available. Several research activities should be incorporated into routine monitoring, e.g. tracking of porphyria, vitamin A deficiencies and evaluation of the avian immune system. Likewise, more research should focus on new areas, e.g. the impact of endocrine disrupting substances and factors regulating chemically-induced genetic mutations.

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Atmospheric Deposition of Toxic Chemicals

SOLEC Indicator #117 - Indicator Matrix

Assessment: Mixed

Purpose
To estimate the annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes and to determine temporal trends in contaminant concentrations. This information will be used to aid in the assessment of potential impacts of toxic chemicals from atmospheric deposition on human health and the Great Lakes aquatic ecosystem, as well as to track the progress of various Great Lakes programs toward virtual elimination of toxic chemicals from the Great Lakes.

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

State of the Ecosystem
The Integrated Atmospheric Deposition Network (IADN) consists of five master sampling sites, one near each of the Great Lakes, and several satellite stations. This joint United States-Canada project has been in operation since 1990. Since that time, thousands of measurements of the concentrations of polychlorinated biphenyls (PCBs), pesticides, polycyclic aromatic hydrocarbons (PAHs), and trace metals have been made at these sites. Concentrations are measured in the atmospheric gas and particle phases and in precipitation. These data have been interpreted in terms of temporal trends and loadings to the Lakes.

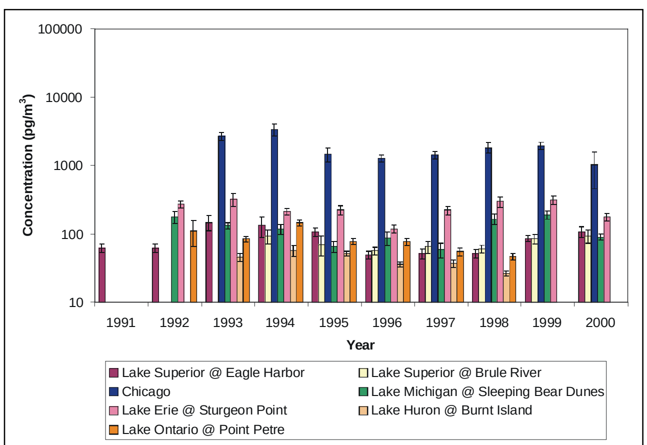

Figure 1. Annual average concentrations of gas-phase ΣPCBs for IADN stations. Error bars represent the standard error for each average.
Source: Buehler, S.S., and Hites, R.A., 2002

Concentrations

Concentrations of gas-phase PCBs (ΣPCB) have generally decreased over time at the master stations (see Figure 1) with half-lives on the order of 3-6 years. ΣPCB is a suite of congeners that make up most of the PCB mass and represent the full range of PCBs. Including more recent data (namely the somewhat higher levels from 1997-1999) lengthens previously calculated half-lives. However, 2000 concentrations show a decrease and preliminary 2001 data show levels nearly the same as those shown for 2000. It is assumed that PCB concentrations will continue to decrease slowly.

The Lake Erie site consistently shows relatively elevated ΣPCB concentrations compared to the other master stations. Higher concentrations for this station are probably due to the proximity of the sampling site to the city of Buffalo, New York. Figure 1 also shows that ΣPCB concentrations at a satellite site in downtown Chicago are an order of magnitude higher that at the other more remote sites.

Gas-phase α-hexachlorocyclohexane (HCH) concentrations are decreasing at all sites, with half-lives of 4-5 years; see Figure 2. This downward trend is, in general, the case for the other banned or restricted pesticides measured by the IADN. Concentrations of organochlorine pesticides in precipitation have also decreased over time. Loadings calculations (see loadings section below) reveal that inputs of measured in-use pesticides (lindane and endosulfan) are generally twice as much as that of the highest banned pesticide, and banned pesticides are volatilizing out of the Lakes in amounts almost 10 times more than the in-use pesticides.

Benzo[*a*]pyrene (BaP), a PAH, is produced by the

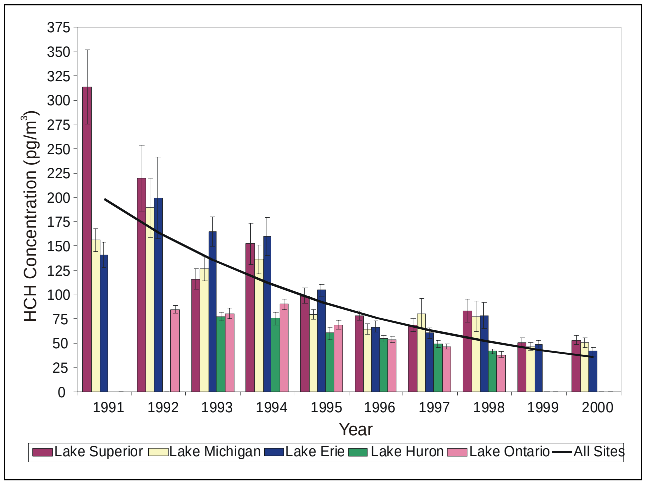

Figure 2. Annual average gas-phase α-HCH concentrations at IADN master stations. The line represents a first-order decrease fitted to the average for all five Lakes.
Source: Buehler, S.S., and Hites, R.A., 2002

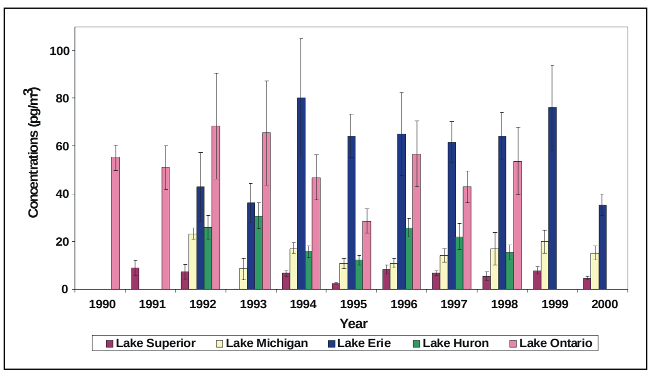

Figure 3. Annual average particle-phase concentrations of Benzo[a]pyrene (BaP).
Source: IADN Steering Committee, 2002

incomplete combustion of almost any fuel and is carcinogenic. Figure 3 shows the annual average particle-phase concentrations of BaP. The concentrations of BaP are relatively high at Lakes Erie and Ontario, sites near major population centers, and the concentrations are relatively unchanged as a function of time at all sites. Concentrations in Chicago, not shown, are about one to two orders of magnitude higher.

Loadings

An atmospheric loading is the amount of a pollutant entering a lake from the air, which equals wet deposition (rain) plus dry deposition (falling particles) plus gas absorption into the water minus volatilization out of the water. Basin-wide loadings are loadings summed over all five Lakes. Annual total basinwide loadings for α-HCH, lindane (γ-HCH), dieldrin, p,p'-DDT, and ΣPCBs are given in Figure 4. A bar pointing downward indicates that the net loading is negative and the compound is volatilizing into the atmosphere. This occurs after the main sources to the air have been cut off and the air becomes "cleaner" relative to the water. The figure shows that the absolute values of the loadings are generally getting smaller, which indicates that the lake water and the air above it are getting closer to being in equilibrium. Note that in 1998, only DDT and lindane still had a net positive deposition to the region. DDT is very close to equilibrium; lindane most likely still has a sizable positive loading because it is currently in use in the region.

Figure 5 shows loadings of metals to Lakes Huron and Ontario over time (data are not available for Lakes Superior, Michigan, and Erie). In general, loadings of metals seemed to decrease during the 1990s but show an increase in 1997 and 1998 for lead and cadmium, mainly due to an increase in wet deposition, which dominates deposition of metals to the Lakes. Loadings for 1997 and 1998 for arsenic and selenium do not include wet deposition, as data were not available. Dry deposition of metals has been consistent over time.

A report on the atmospheric loadings of these compounds to the Great Lakes has recently been published for data through 1998. It is available online at: <<http://www.msc.ec.gc.ca/iadn/Resources/resources_e.html>>.
To receive a hardcopy, please contact one of the agencies listed at the end of this report.

Future Pressures

Pressure on the Lakes from atmospheric deposition of toxic compounds is likely to continue into the future. Compounds no longer in use, such as most of the organochlorine pesticides, may decrease to undetectable levels, especially if they are phased out in developing countries, as is being called for in international agreements.

Residual sources of PCBs remain in the U.S. and throughout the world; therefore, atmospheric deposition will still be significant at least decades into the future. PAHs and metals continue to be emitted and therefore concentrations of these

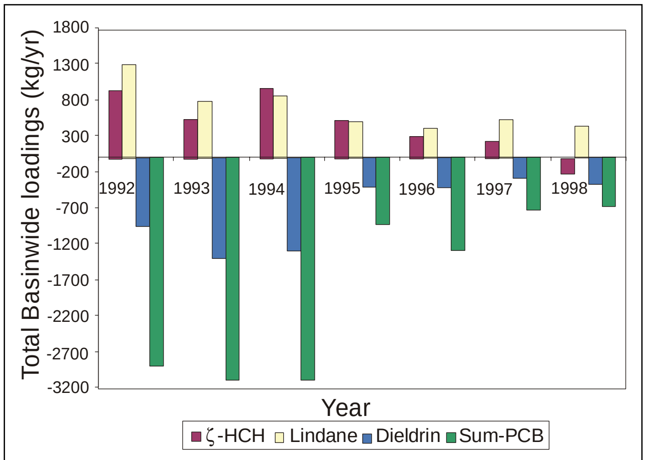

Figure 4. Annual total basinwide loadings for α-HCH, lindane, dieldrin, and ΣPCBs.
Source: Buehler *et al.*, 2001

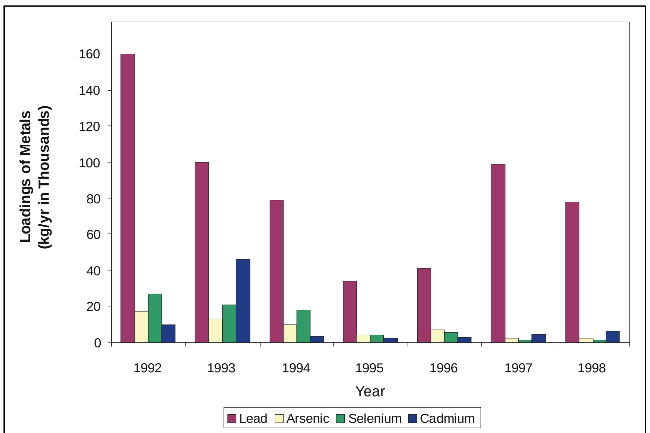

Figure 5. Annual loadings of metals to Lakes Huron and Ontario combined. Data are not available for Lakes Superior, Michigan and Erie.
Source: Buehler *et al.*, 2001

substances may not decrease or decrease very slowly. Currently released substances not monitored by IADN, including mercury, other in-use pesticides, and dioxins and furans, will also present a threat into the future.

Atmospheric deposition of "emerging" chemicals of concern, such as brominated flame retardants and other compounds that may currently be under the radar, could also serve as a future stressor on the Great Lakes.

Future Activities
In terms of in-use agricultural chemicals, such as lindane, further restrictions on the use of these compounds may be warranted. Controls on the emissions of combustion systems, such as factories and motor vehicles, may induce a decline in the input of PAHs to the Great Lakes' atmosphere.

Remaining sources of PCBs, such as contaminated sediments, sewage sludge, and in-use electrical equipment, could perhaps be addressed more systematically through efforts like the Canada-US Binational Toxics Strategy and EPA's Persistent Bioaccumulative Toxics (PBT) Program. Many of these sources are located in urban areas, which is reflected by the higher levels of PCBs measured in Chicago. Research to investigate the significance of these remaining sources is underway. Such work will help prioritize PCB disposal and remediation projects in order to further reduce atmospheric deposition. This is important since fish consumption advisories for PCBs exist for all five Great Lakes.

Voluntary pollution prevention activities, technology-based pollution controls, and chemical substitution (for pesticides and industrial chemicals) can aid in reducing the amounts of toxic chemicals deposited to the Great Lakes. Efforts to achieve reductions in use and emissions of toxics worldwide through international assistance and negotiations should also be supported.

Further Work Necessary
The Integrated Atmospheric Deposition Network (IADN) should continue. Only through long-term monitoring of the atmosphere will it become clear if reduction efforts have been effective.

In order to more fully characterize atmospheric deposition to the lakes, Environment Canada and USEPA are adding analytes such as mercury, dioxins, and polybrominated diphenyl ethers to the list of those monitored at selected sites as funding allows. USEPA and Indiana University have recently installed a monitoring station in Cleveland, Ohio, in order to obtain additional information on the influence of urban areas on deposition to the Lakes.

Acknowledgments
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Sources
Concentration trend figures were contributed by Stephanie Buehler, Ron Hites, and Ilora Basu of Indiana University.

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IADN Steering Committee, 2002, unpublished.

Contaminants in Edible Fish Tissue

Indicator ID # 4083 - Indicator Matrix

Assessment: Mixed Improving

Purpose
To assess the historical trends of the edibility of fish in the Great Lakes using fish contaminant data and a standardized fish advisory protocol. The approach is illustrated using the Great Lakes protocol for PCBs as the standardized fish advisory benchmark applied to historical data to track trends in fish consumption advice. US EPA GLNPO salmon fillet data (Minnesota DNR salmon fillet data for Lake Superior) are used as a starting point to demonstrate the approach. Unfortunately data gaps and data variability with the GLNPO salmon fillet data do not allow us to discern statistically significant trends.

Ecosystem Objective
Overall Human Health Objective: The health of humans in the Great Lakes ecosystem should not be at risk from contaminants of human origin. Fish and wildlife in the Great Lakes ecosystem should be safe to eat; consumption should not be limited by contaminants of human origin.

Annex 2 of the GLWQA requires LaMPs to define "…the threat to human health posed by critical pollutants… including beneficial use impairments."

State of the Ecosystem
Since the 1970's, there have been declines in many persistent bioaccumulative toxic (PBT) chemicals in the Great Lakes basin. However, PBT chemicals, because of their ability to bioaccumulate and persist in the environment, continue to be a significant concern.

Fish Consumption Programs are well established in the Great Lakes. States, tribes, and the province of Ontario have extensive fish contaminant monitoring programs and issue advice to their residents about how much fish and which fish are safe to eat. This advice ranges from recommendations to not eat any of a particular size of certain species from some water bodies, to recommending that people can eat unlimited quantities of other species and sizes.

Lake	Contaminants on which Fish Advisories are based on in Canada and the United States
Superior	PCBs, mercury, toxaphene, chlordane, dioxin
Huron	PCBs, mercury, dioxin, chlordane, toxaphene
Michigan	PCBs, mercury, dioxin, chlordane
Erie	PCBs, dioxin, dioxinmercury
Ontario	PCBs, mercury, mirex, toxaphene, dioxin

Figure 1. Contaminants on which Fish Advisories are based in Canada and the United States.
Source: Sandy Hellman, U.S. Environmental Protection Agency, Great Lakes National Program Office

Advice from these agencies to limit consumption of fish is mainly due to levels of PCBs, mercury, chlordane, dioxin, and toxaphene in the fish. The contaminants are listed by lake, in the following table.

Lake Contaminants that Fish Advisories are based on in Canada and United States State, tribal and provincial governments provide information to consumers regarding consumption of sport-caught fish. This information is not regulatory-its guidance, or advice. Although some states use the Federal commercial-fish guidelines for the acceptable level of contaminants when giving advice for eating sport caught fish, consumption advice offered by most agencies is based on human health risk. This approach involves interpretation of studies on health effects from exposure to contaminants. Each state or province is responsible for developing advisories for protecting the public from pollutants in fish and tailoring this advice to meet the health needs of its citizens. As a result, the advice from state and provincial programs is sometime different for the same lake and speices within that lake.

Future Pressures

Organochlorine contaminants in fish in the Great Lakes are generally decreasing. As these contaminants decline mercury will become a more important contaminant of concern regarding the edibility of the fish. Emerging contaminants, such as certain brominated flame-retardants, are increasing in the environment and causing concern. Screening studies on a larger suite of chemcials is needed. The health effects of multiple contaminants, including endocrine disruptors, need to be addressed.

Future Actions

To protect human health, actions must continue to be implemented on a number of levels. Reductions and monitoring of contaminant levels in environmental media and in human tissues is an activity in particular need of support. Health risk communication is also a crucial component to protecting and promoting human health in the Great Lakes.

There is a need for surveillance to evaluate how much fish people eat and biomonitoring to determine actual tissue levels, particularly within sensitive populations.

Further Work Necessary

1. Evaluation of historical data: the long-term fish contaminant monitoring data sets that have been assembled by several jurisdictions for different purposes need to be more effectively utilized. Relationships need to be developed that allow for comparison and combined use of existing data from the various sampling programs. These data could be used in

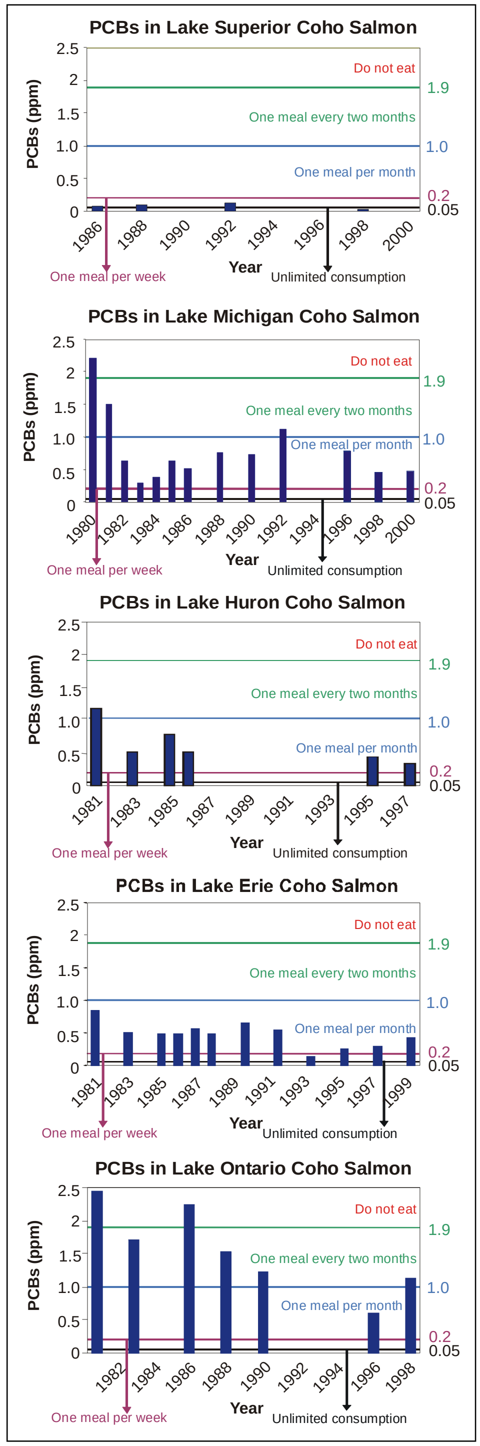

Figure 2. Results of a uniform fish advisory protocol applied to historical data (PCBs, coho salmon) in the Great Lakes. Blank indicates no sampling.

Source: Sandy Hellman, U.S. Environmental Protection Agency-Great Lakes National Program Office

expanding this indicator to other contaminants and species and for supplementing the data used in this illustration.
2. Coordination of future monitoring.
3. Agreement on fish advisory health benchmarks for the contaminants that cause fish advisories in the Great Lakes. Suggested starting points are: The Great Lakes Protocol for PCBs, US EPA IRIS RfD for mercury, and Health Canada's TDI for toxaphene.

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Authors: Sandy Hellman, USEPA Great Lakes National Program Office, Chicago, IL and Patricia McCann, Minnesota Department of Health, St. Paul, MN.

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Air Quality

SOLEC Indicator #4176 - Indicator Matrix

Assessment: Mixed

Purpose
To monitor the air quality in the Great Lakes ecosystem, and to infer the potential impact of air quality on human health in the Great Lakes basin.

Ecosystem Objective
Air should be safe to breathe. Air quality in the Great Lakes ecosystem should be protected in areas where it is relatively good, and improved in areas where it is degraded.

State of the Ecosystem
Overall, there has been significant progress in reducing air pollution in the Great Lakes basin. For most substances of interest, both emissions and ambient concentrations have decreased over the last ten years or more. However, progress has not been uniform and differences in weather from one year to the next complicate analysis of ambient trends. Ozone can be particularly elevated during hot summers. Drought conditions result in more fugitive dust emissions from roads and fields, increasing the ambient levels of particulate matter.

In general, there has been significant progress with urban/local pollutants over the past decade or more, though somewhat less in recent years, with a few remaining problem districts. Ground-level ozone and fine particles remain a concern in the Great Lakes region, especially in the Windsor-to-Ottawa corridor and the Lake Michigan basin. These pollutants continue to exceed their Ambient Air Quality Criteria (AAQC) at a majority of monitoring locations in Southern Ontario. As well, an increased emphasis has been placed on monitoring finer fractions of particulate matter (PM_{10} and $PM_{2.5}$) due to known negative health effects.

For the purposes of this discussion, the pollutants can be divided into urban (or local) and regional pollutants. For regional pollutants, transport is a significant issue, from hundreds of kilometers to the scale of the globe; formation from other pollutants, both natural and man-made, can also be important. Unless otherwise stated, references to the U.S. or Canada in this discussion refer to the respective portions of the Great Lakes basin. Latest published air quality data are for 2000 (Canada – Ontario and the U.S.).

Urban/Local Pollutants
Carbon Monoxide (CO): In the U.S., CO ambient levels have decreased approximately 41 percent over 1991 to 2000, and 61 percent over 1981 to 2000. Currently, there are no non-attainment areas in the U.S. for CO. Nationally, U.S. emissions of CO decreased five percent from 1991 to 2000, and 18 percent from 1981 to 2000. Over Canada, there has been a 30 to 40 percent reduction in composite site concentration over 1988 to 1997, with a 33 to 39 percent reduction in Ontario for the period 1991 to 2000. Emissions have decreased nationally by 17 percent since 1988 with a 4.1 percent decline in Ontario between 1991 and 2000. These declines are mainly the result of more stringent transportation emission standards.

Nitrogen Dioxide (NO_2): Over Canada, average ambient NO_2 levels have remained relatively constant since the early 1990's. Ontario concentrations have declined slightly in the range of 5 to10 percent during the period 1991 to 2000. Canadian emissions of nitrogen oxides (NO_x), the family of nitrogen oxides, increased slightly from 1980 to 2000. In the U.S., ambient concentrations decreased 11 percent from 1991 to 2000, but remain unchanged in the Lake Michigan area. There are currently no NO_2 non-attainment areas in the U.S. In the U.S., emissions of NO_x increased by approximately three percent from 1991 to 2000. (For more information on oxides of nitrogen, please refer to the SOLEC Indicator Report #9000 Acid Rain.)

Sulfur Dioxide (SO_2): From 1991 to 2000, ambient concentrations of SO_2 in the U.S. decreased 37 percent. There are three non-attainment areas in the Great Lakes region for SO_2 (Lake County, Indiana; Cleveland-Akron-Lorain, Ohio; and Toledo, Ohio). National SO_2 emissions in the U.S. were reduced 27 percent from 1990 to 2000. Canadian ambient levels have remained fairly constant since 1994, with two violations of the one-hour criteria in 2000 (Sudbury and Mississauga). Canadian emissions decreased 45 percent from 1980 to 2000, but have remained relatively constant since 1995. Even with increasing economic activity, emissions remain below the target national emission cap. (For more information on sulfur dioxide, please refer to the SOLEC Indicator Report #9000 Acid Rain.)

Lead: U.S. concentrations decreased 93 percent from 1981 to 2000 and 50 percent from 1991 to 2000. There are no non-attainment areas for lead in the Great Lakes region. National lead emissions in the U.S. decreased 94 percent from 1981 to 2000, but only four percent from 1991 to 2000, as a result of regulatory efforts to reduce the content of lead in gasoline. Similar improvements in Canada have followed with the usage of unleaded gasoline, with only isolated exceedances of ambient criteria near industrial sites.

Total Reduced Sulfur (TRS): This family of compounds is of concern in Canada due to odor problems, normally near industrial or pulpmill sources. Ambient concentrations are significantly lower than in the early 1990's with a decrease of 33.3 percent during the period of 1991 to 2000. This decline parallels emission reductions, though there is little trend in recent years. There are still periods that are above the ambient criteria near a few centers.

PM_{10}: The U.S. National Ambient Air Quality Standard (NAAQS) addresses PM_{10} (particles with a diameter of 10 microns or less). Ambient concentrations in the U.S. have decreased 19 percent from 1991 to 2000. There are currently three non-attainment areas in the Great Lakes region (two in Cook County, Illinois; and one in Lake County, Indiana). National direct source man-made emissions decreased 47 percent from 1981 to 2000, but only six percent from 1991 to 2000. Canadian objectives have focused on Total Suspended Particulate matter (TSP). Both PM_{10} and TSP affect locations relatively close to pollutant sources. Since 1997 there has been an interim Ontario PM_{10} objective of 50µg/m3, with the number of ambient PM monitors having more than doubled from 20 in 1996 to 43 in 2000. Emissions decreased from 1988 to 1992, but have shown no significant trend since that time. Five of the 10 real-time ambient PM_{10} monitors (all in urban areas) recorded exceedances of the interim objective in 2000.

Regional Pollutants

Ground-Level Ozone (O_3): Ozone is almost entirely a secondary pollutant, which forms from reactions of precursors (VOCs-volatile organic compounds and NO_x - oxides of nitrogen) in the presence of heat and sunlight. Ozone is a problem pollutant over broad areas of the Great Lakes region, except for the Lake

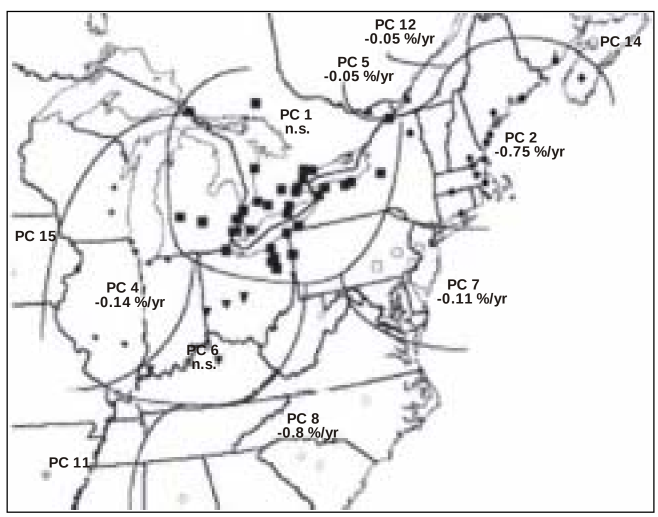

Figure 1. Regional meteorologically adjusted trends (%/yr) in 1-hr averaged ozone in the northern United States and southern Canada using cluster analysis.
Source: 1980-1993 from NARSTO, 2000

Superior basin. National assessments find some uneven improvement in peak levels, but with indications that average levels may be increasing on a global scale (NARSTO 2000). Local onshore circulations around the Great Lakes can exacerbate the problem, as pollutants can remain trapped for days below the maritime inversion. Consistently high levels are found in provincial parks near Lakes Huron and Erie, and western Michigan is impacted by transport across Lake Michigan from Chicago. In the U.S., high 1-hour concentrations have decreased 10 percent from 1991 to 2000, while 8-hour ozone concentrations have only decreased 7 percent during the same period. There are eight ozone non-attainment areas in the Great Lakes basin (Chicago, Illinois; Lake and Porter Counties, Indiana; Milwaukee, Wisconsin; Manitowoc County, Wisconsin; Door County, Wisconsin; Erie, Pennsylvania; Buffalo-Niagara Falls, New York; and Jefferson County, New York). VOC emissions have decreased 16 percent and NO_x emissions have increased three percent from 1991 to 2000. In Canada, there has been little trend in the number of exceedances of the ozone objective in the 1990s, and mean annual levels increase. Man-made VOC emissions have decreased about 17 percent since 1991, although most of this decrease occurred in the period 1991 to 1996, with emissions fairly constant since 1996. NO_x emissions have remained fairly constant since 1995 with a slight increase in overall emissions since 1990.

$PM_{2.5}$: This fraction of particulate matter (diameter 2.5 microns or less) is of health concern because it can penetrate deeply into the lungs, in contrast to larger particles. $PM_{2.5}$ is mostly a secondary pollutant, produced from both natural and man-made precursors (SO_2, NO_x, and ammonia). A Canada-Wide-Standard (CWS) threshold of 30 µg/m3 (24-hour average, based on the 98th percentile ambient measurement) was established in June 2000. As $PM_{2.5}$ monitoring has only begun quite recently, there are not enough data to show a national long-term trend in urban concentrations. In Ontario, based on continuous monitoring of $PM_{2.5}$ conducted at 14 sites in 2000, 93 percent of the sites exceeded 30 µg/m3 (24-hour average), however only two locations, Hamilton Downtown and Sarnia, exceeded the CWS 98th percentile threshold. As of August 2002, Ontario has also introduced $PM_{2.5}$ into their Air Quality Index and Smog Advisory Programs, with an exceedance threshold set at 45 µg/m3 (3-hour average). In the U.S., there are not enough years of data from the recently established reference-method network to determine trends, but it appears that there may be many areas which do not attain the new U.S. standard (annual average of 15 µg/m3 and 24-hour average of 65 µg/m3).

Air Toxics: This term captures a large number of pollutants that, based on the toxicity and likelihood for exposure, have potential to harm human health (e.g. cancer) or cause adverse environmental and ecological effects. Some of these are of local importance, near to sources, while others may be transported over long distances. Monitoring is difficult and expensive, and usually limited in scope. Usually such toxic air pollutants are present only at trace levels. In both Canada and the U.S., efforts focus on minimizing emissions. In the U.S. the Clean Air Act targets a 75% reduction in cancer "incidence", and "substantial" reduction in non-cancer risks. The maximum available control technology (MACT) program sets emissions standards on industrial sources to reduce emissions of air toxics. Once fully implemented, these standards will cut emissions of toxic air pollutants by nearly 1.5 million tons per year from 1990 levels. In Canada key toxics such as benzene, mercury, dioxins, and furans are the subject of ratified and proposed new standards, and voluntary reduction efforts. Some ambient trends have also been found. In the U.S., concentrations of benzene and toluene have shown significant decreases from 1993 to 1998, notably in the Lake Michigan region due to the use of reformulated gasoline. Styrene has also shown a significant decrease from 1996 to 1998.

Emissions are being tracked through the National Pollutant Release Inventory (NPRI-Canada), the U.S. National Toxics Inventory (NTI), and the Great Lakes Regional Air Toxics Emissions Inventory. NTI data indicate that national U.S. toxic emissions have dropped 23 percent between 1990 and 1996, though emission estimates are subject to modification, and the trends are different for different compounds. In Canada, NPRI information includes information on significant voluntary reductions in toxic emissions through the ARET (Accelerated Reduction/ Elimination of Toxics) program. The Great Lakes Toxics Inventory is an ongoing initiative of the regulatory agencies in the eight Great Lakes States and the Province of Ontario. Emissions inventories have been developed for 1996, 1997 and 1998, but different approaches were used to develop these inventories making trend analysis difficult.

Future Pressures

Continued population growth and associated urban sprawl are threatening to offset emission reduction efforts and better control technologies, through both increased vehicle-miles traveled and energy consumption. The changing climate may affect the frequency of weather conditions conducive to high ambient concentrations of many pollutants. There is also increasing evidence of changes to the atmosphere as a whole. For example, average ground level ozone concentrations may be increasing on a global scale. Continuing health research is both broadening the number of toxics, and producing evidence that existing standards should be lowered. There is epidemiological evidence of health effects from ozone or fine particulates down to or below levels previously considered to be background or “natural” levels of 30-50 ppb (daily maximum hourly values).

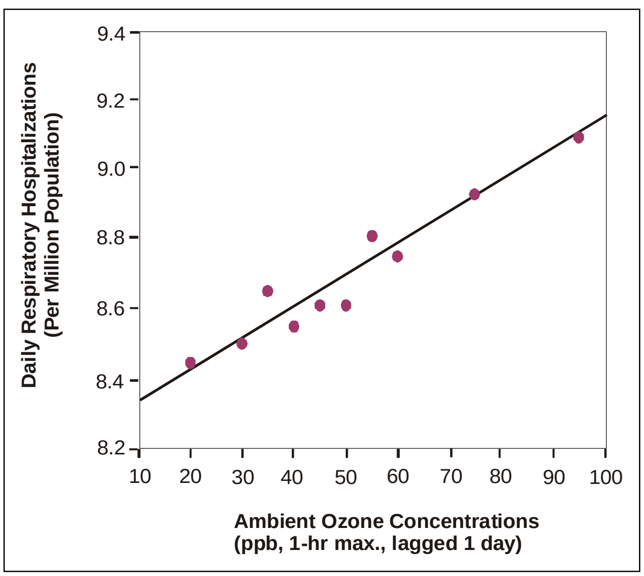

Figure 2. Association of respiratory admissions to Ontario hospitals with ozone pollution. National Air Quality Objectives for Ground-Level Ozone: Science Asssessment.
Source: Environment Canada, 1999

Future Activities

Major pollution reduction efforts continue in both U.S. and Canada. In Canada, new ambient standards for particulate matter and ozone have been endorsed, with a 2010 attainment date. This will involve updates at the Federal level and at the provincial level (Ontario Anti-Smog Action Plan). Toxic air pollutants are also addressed at both levels. The Canadian Environmental Protection Act (CEPA) was recently amended. In the U.S., new, more protective ambient air standards have been promulgated for ozone and particulate matter. MACT (Maximum Available Control Technology) standards continue to be promulgated for sources of toxic air pollution. USEPA has also begun looking at the risk remaining after emissions reductions for industrial sources take effect.

At the international level, Canada and the U.S. signed the Ozone Annex to the Air Quality Agreement in December 2000. The Ozone Annex commits both countries to emission reductions from the major sources of NO_x and VOCs, thereby helping both countries attain their ozone air quality goals to protect human health and the environment. Canada estimates that total NO_x reduction in the Canadian transboundary region will be 44 percent year round by 2010. The U.S. estimates that the total NO_x reductions in the U.S. transboundary region will be 36 percent year-round by 2010 and 43 percent during the ozone season. Canada and the U.S. have also undertaken cooperative modeling, monitoring, and data analysis and developed a work plan to address transboundary PM issues. Their objective is to issue a report on transboundary PM issues by the end of 2003 that will be the focus of decision making on whether to develop a PM Annex to the Air Quality Agreement. Efforts to reduce toxic pollutants will also continue under NAFTA and through UN-ECE protocols.

Further Work Necessary

$PM_{2.5}$ networks will continue to develop in both countries, to determine ambient levels, trends, and consequent reduction measures. Review of standards or objectives will continue to consider new information. The U.S. is considering deployment of a national toxic monitoring network.

Limitations
It must be emphasized that this indicator report does not consider indoor air quality, or allergens. The monitoring networks are urban-focused, and are considered deficient for toxic pollutants.

Acknowledgments
Authors: Bryan Tugwood, Environment Canada, Meteorological Services of Canada, Downsview, ON; Todd Nettesheim, U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL; and Michael Rizzo, U.S. Environmental Protection Agency, Air and Radiation Division, Chicago, IL.

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Ice Duration on the Great Lakes
SOLEC Indicator #4858 - Indicator Matrix

Assessment: Mixed Deteriorating (with respect to climate change)

Purpose
To assess the ice duration and thereby the temperature and accompanying physical changes to each lake over time, in order to infer the potential impact of climate change.

Ecosystem Objective
This indicator is used as a potential assessment of climate change, particularly within the Great Lakes basin. Changes in water and air temperatures will influence ice development on the Lakes and, in turn, affect coastal wetlands, nearshore aquatic environments, and inland environments.

State of the Ecosystem
Air temperatures over a lake are one of the few factors that control the formation of ice on that surface. Colder winter temperatures increase the rate of heat released by the lake, thereby increasing the freezing rate of the water. Milder winter temperatures have a similar controlling effect, only the rate of heat released is slowed and the ice forms more slowly. Globally, some inland lakes appear to be freezing up at later dates, and breaking-up earlier, than the historical average, based on a study of 150 years of data (Magnuson *et al*., 2000). These trends, as the authors put it, add to the evidence that the earth has been in a period of global warming for at least the last 150 years.

The freezing and thawing of lakes is a very important aspect to many aquatic and terrestrial ecosystems. Many fish species rely on the ice to give their eggs protection against predators during the late part of the ice season. Nearshore ice has the ability to change the shoreline as it can encroach upon the land during winter freeze-up times. Even inland systems are affected by the amount of ice that forms, especially within the Great Lakes basin. Less ice on the Great Lakes allows for more water to evaporate and be spread across the basin in the form of snow. This can have an affect on the foraging animals (like deer), who, need to dig through snow during the winter in order to obtain food.

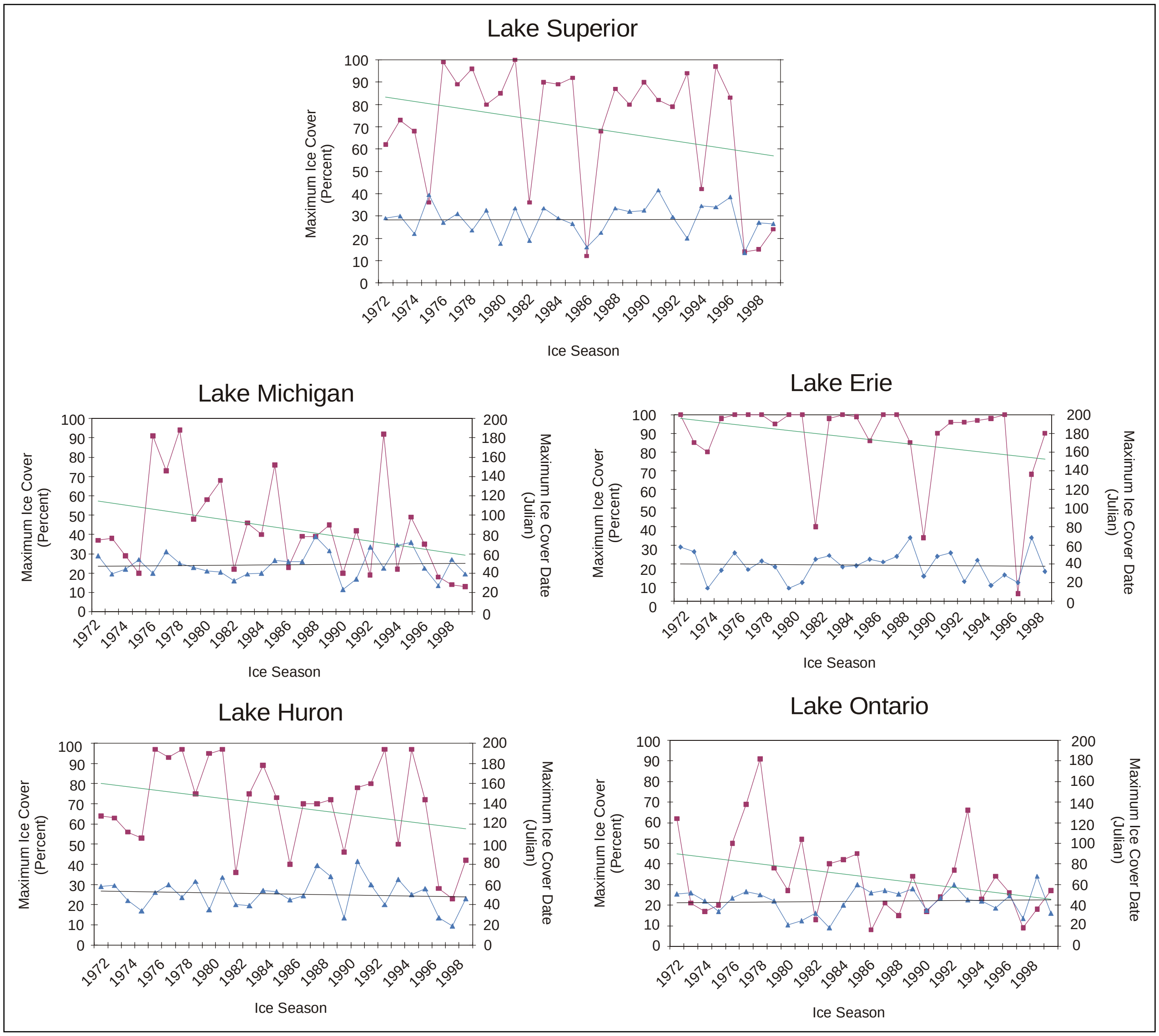

Figure 1.Trends of maximum ice cover and the corresponding date on the Great Lakes, 1972-2000. Source: National Oceanic and Atmospheric Administration

Observations of the Great Lakes data showed no real conclusive trends with respect to the date of freeze-up or break-up. A reason for this could be that due to the sheer size of the lakes, it wasn't possible to observe the whole lake during the winter season (at least before satellite imagery), and therefore only regional observations were made (inner bays and ports). However, there was enough data collected from the ice charts to make a statement concerning the overall ice cover during the season. There appears to be a decrease in the maximum ice cover per season over the last thirty years (figure 1).

The trends on each of the five lakes show that during this time span the maximum amount of ice forming each year has been decreasing, which, in-fact, can be correlated to the average ice cover per season observed for the same time duration (figure 2). Between the 1970's and 1990's there was at least a ten percent decline in the maximum ice cover on each lake, and almost as much as 18% in some cases, with the greatest decline occurring during the1990's. Since a complete freeze-up did not occur on all the Great Lakes, a series of inland lakes (known to freeze every winter) in Ontario were looked at to see if there

Lake	1970-1979	1980-1989	1990-1999	Change from 1970s to 1990s
Erie	94.5	90.8	77.3	-17.2
Huron	71.3	71.7	61.3	-10.0
Michigan	50.2	45.6	32.4	-17.8
Ontario	39.8	29.7	28.1	-11.7
Superior	74.5	73.9	62.0	-12.6

Figure 2. Mean Ice coverage, in percent, during the corresponding decade.
Source: National Oceanic and Atmospheric Administration

was any similarity to the results in the previous studies. Data from Lake Nipissing and Lake Ramsey were plotted (Figure 3) based on the ice-on date (complete freeze-over date) and the break-up date (ice-off date). As it turns out, the freeze-up date for Lake Nipissing appears to have the same trend as the other global inland lakes: freezing over later in the year. Lake Ramsey however, seems to be freezing over earlier in the season. The ice-off date for both however, appear to be increasing, or occurring at later dates in the year. These results contradict what is said to be occurring with other such lakes in the Northern Hemisphere (see Magnuson *et al*., 2000).

Future Pressures
Based on the results of figure 1 and table 1, it seems that ice formation of the Great Lakes should continue to decrease in total cover, if the predictions on global atmospheric warming are true. Milder winters will have a drastic effect on how much of the lakes are covered in ice, which in turn, will have an effect on many aquatic and terrestrial ecosystems that rely on lake ice for protection and food acquisition. However, because only a small number of data sets were collected and analyzed for this study, this is not conclusive. To reach a level of significance that would be considered acceptable, more data on lake ice formation would have to be gathered.

Future Activities
Increased winter and summer air temperatures appear to be the greatest influence on ice formation. Currently there are certain protocols, on a global scale, that are being introduced in order to reduce the emission of greenhouse gases. The most substantial of these is the Kyoto Protocol, which looks at decreasing the emissions of greenhouse gases by 2008, with a large amount of attention on decreasing carbon dioxide. Countries that have not agreed to adhere to this protocol are taking other measures to reduce their emissions.

Further Work Necessary
While the data for the Great Lakes is easily obtained from 1972-present, smaller inland lakes, which may be affected by climate change at a faster rate, should be looked into. As much historical information that is available should be obtained. The more data that is received will increase the statistical significance of

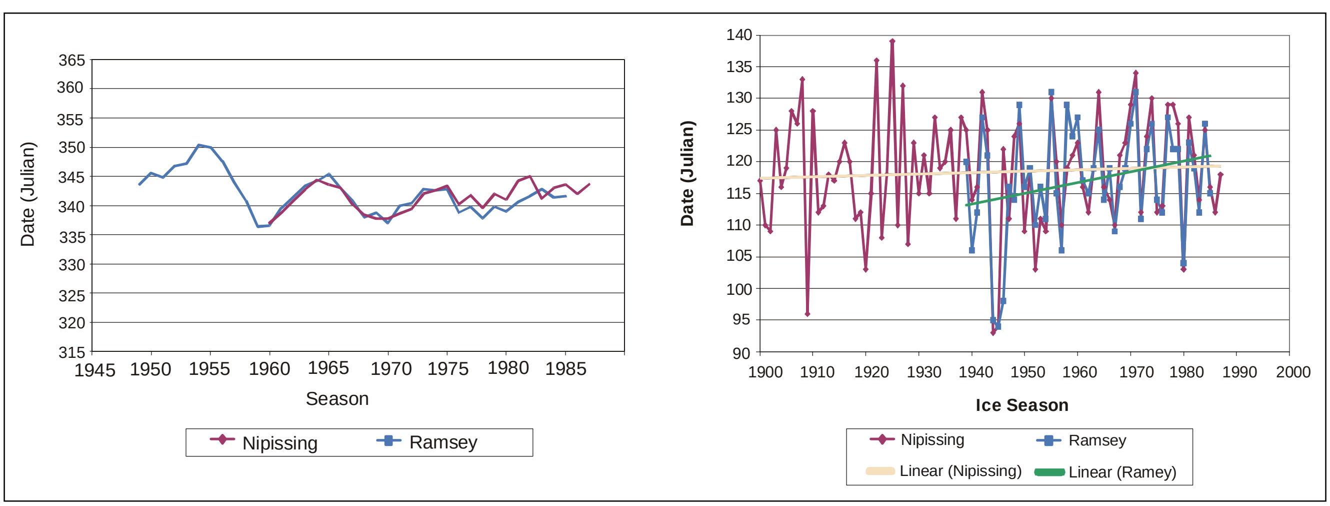

Figure 3. Ice-on and ice-off dates for Lake Nipissing (black dashed line) and Lake Ramsey (pink solid line). Data were smoothed using a 5-year moving average.
Source: Climate and Atmospheric Research, Environment Canada

the results, and therefore have greater meaning in the end. It would convenient for the results to be reported every four to five years (at least for the Great Lakes), and quite possibly a shorter time span for any new inland lake information. It may also be feasible to subdivide the Great Lakes into bays and inlets, etc., in order to get an understanding of what is occurring in nearshore environments.

Acknowledgments
Author: Gregg Ferris, Environment Canada Intern, Downsview, ON.
All data analyzed and charts created by the author.

Sources

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Ice charts obtained from the National Oceanic and Atmospheric Administration (NOAA) and the Canadian Ice Service (CIS).

Data for Lake Nipissing and Lake Ramsey obtained from Walter Skinner, Climate and Atmospheric Research, Environment Canada-Ontario Region.

Extent of Hardened Shoreline

SOLEC Indicator #8131 - Indicator Matrix
Note: this indicator report is from 2000

Assessment: Mixed Deteriorating

Purpose
This indicator assesses the extent of hardened shoreline through construction of sheet piling, rip rap, or other erosion control structures.

Ecosystem Objective
Shoreline conditions should be healthy to support aquatic and terrestrial plant and animal life, including the rarest species.

Anthropogenic hardening of the shorelines not only directly destroys natural features and biological communities, it also has a more subtle but still devastating impact. Many of the biological communities along the Great Lakes are dependent upon the transport of shoreline sediment by lake currents. Altering the transport of sediment disrupts the balance of accretion and erosion of materials carried along the shoreline by wave action and lake currents. The resulting loss of sediment replenishment can intensify the effects of erosion, causing ecological and economic impacts. Erosion of sand spits and other barriers allows increased exposure and loss of coastal wetlands. Dune formations can be lost or reduced due to lack of adequate nourishment of new sand to replace sand that is carried away. Increased erosion also causes property damage to shoreline properties.

State of the Ecosystem
The National Oceanic and Atmospheric Administration (NOAA) Medium Resolution digital Shorelines dataset was compiled between 1988 and 1992. It contains data on both the Canadian and U.S. shorelines, using aerial photography from 1979 for the state of Michigan and from 1987-1989 for the rest of the basin.

From this dataset, shoreline hardening has been categorized for each Lake and connecting channel. Figure 1 indicates the percentages of shorelines in each of these categories. The St. Clair, Detroit, and Niagara Rivers have a higher percentage of their shorelines hardened than anywhere else in the basin.

Lake/ Connecting Channel	70-100% Hardened	40-70% Hardened	15-40% Hardened	0-15% Hardened	Non-structural Modifications	Unclassified
Lake Superior	3.1	1.1	3.0	89.4	0.03	3.4
St. Marys River	2.9	1.6	7.5	81.3	1.6	5.1
Lake Huron	1.5	1.0	4.5	91.6	1.1	0.3
Lake Michigan	8.6	2.9	30.3	57.5	0.1	0.5
St. Clair River	69.3	24.9	2.1	3.6	0.0	0.0
Lake St. Clair	11.3	25.8	11.8	50.7	0.2	0.1
Detroit River	47.2	22.6	8.0	22.2	0.0	0.0
Lake Erie	20.4	11.3	16.9	49.1	1.9	0.4
Niagara River	44.3	8.8	16.7	29.3	0.0	0.9

Figure 1. Percentages of shorelines in each category of hardened shoreline.The St. Clair, Detroit and Niagara Rivers have a higher percentage of their shorelines hardened than anywhere else in the basin. Lake Erie has the highest percentage of its shoreline hardened, and Lakes Huron and Superior have the lowest.
Source: National Oceanic and Atmospheric Administration

Of the Lakes themselves, Lake Erie has the highest percentage of its shoreline hardened, and Lakes Huron and Superior have the lowest.

In 1999, Environment Canada assessed change in the extent of shoreline hardening along about 22 kilometers of the Canadian side of the St. Clair River from 1991-1992 to 1999. Over the 8-year period, an additional 5.5 kilometers (32 percent) of the shoreline had been hardened. This is clearly not representative of the overall basin, as the St. Clair River is a narrow shipping channel with high volumes of Great Lakes traffic. This area also has experienced significant development along its shorelines, and many property owners are hardening the shoreline to reduce the impacts of erosion.

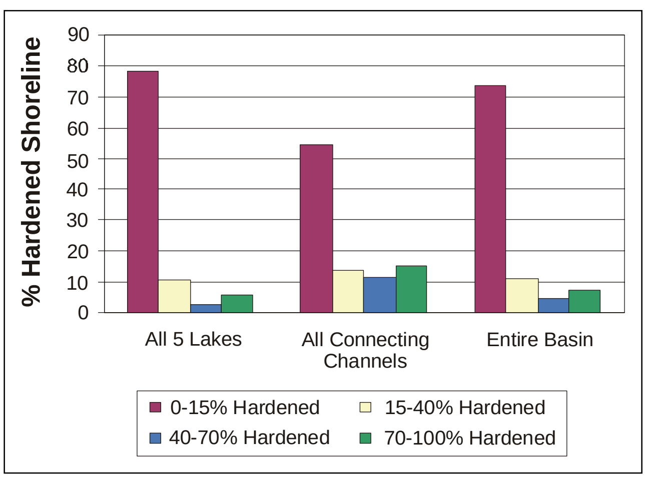

Figure 2. Shoreline hardening in the Great Lakes compiled from 1979 data for the state of Michigan and 1987-1989 data for the rest of the basin.
Source: Environment Canada and National Oceanic Atmospheric Administration

Future Pressures on the Ecosystem
Shoreline hardening is not generally reversible, so once a section of shoreline has been hardened, it can be considered a permanent feature. As such, the current state of shoreline hardening likely represents the best condition that can be expected in the future.

Pressure will continue to harden additional stretches of shoreline, especially during periods of high lake levels. This additional hardening in turn will starve the downcurrent areas of sediment to replenish that which eroded away, causing further erosion and further incentive for additional hardening. Thus, a cycle of shoreline hardening can progress along the shoreline.

The future pressures on the ecosystem resulting from existing hardening will almost certainly continue, and additional hardening is likely in the future. The uncertainly is whether the rate can be reduced and ultimately halted. In addition to the economic costs, the ecological costs are of concern, particularly the

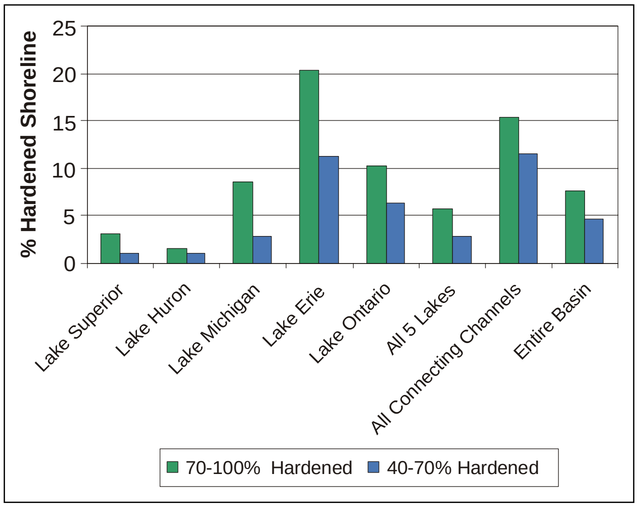

Figure 3. Shoreline hardening by Lake compiled from 1979 data for the state of Michigan and 1987-1989 data for the rest of the basin.
Source: Environment Canada and National Oceanic Atmospheric Administration

further lost or degradation of coastal wetlands and sand dunes.

Future Actions
Shoreline hardening can be controversial, even litigious, when one property owner hardens a stretch of shoreline that may increase erosion of an adjacent property. The ecological impacts are not only difficult to quantify as a monetary equivalent, but difficult to perceive without an understanding of sediment transport along the lakeshores. The importance of the ecological process of sediment transport needs to be better understood as an incentive to reduce new shoreline hardening. An educated public is critical to ensuring wise decisions about the stewardship of the Great Lakes basin ecosystem, and better platforms for getting understandable information to the public is needed.

Further Work Necessary
It is possible that more recent aerial photography of the shoreline will be interpreted to show more recently hardened shorelines. Once more recent data provides information on hardened areas, updates may only be necessary basinwide every 10 years, with monitoring of high-risk areas every 5 years.

Acknowledgments
Authors: John Schneider, USEPA Great Lakes National Program Office, Chicago, IL, Duane Heaton, USEPA Great Lakes National Program Office, Chicago, IL, and Harold Leadlay, Environment Canada, Environmental Emergencies Section, Downsview, ON.

Sources
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Contaminants Affecting Productivity of Bald Eagles
SOLEC Indicator #8135 - Indicator Matrix

Assessment: Mixed Improving

Purpose
This indicator assesses the number of territorial pairs, success rate of nesting attempts, and number of fledged young per territorial pair as well as the number of developmental deformities in young. The concentrations of persistent organic pollutants and selected heavy metals are also determined in unhatched bald eagle eggs, and in nestling blood and feathers. Data will be used to infer the potential for harm to other wildlife caused by eating contaminated prey items.

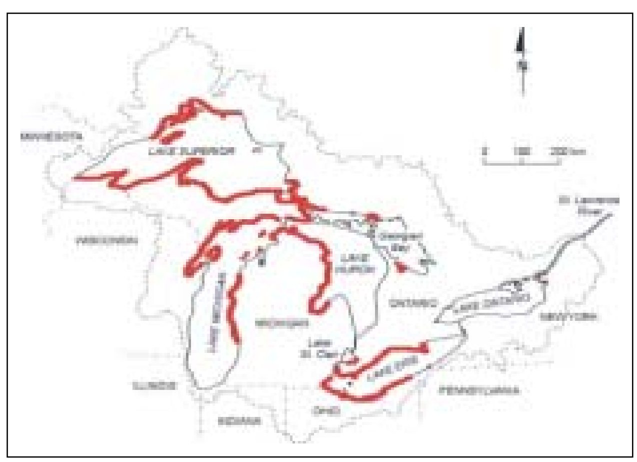

Figure 1. Approximate nesting locations of bald eagles along the Great Lakes shorelines, 2000.
Source: W. Bowerman, Clemson University, Lake Superior LaMPs, and for Lake Ontario, Peter Nye, and N.Y. Department of Environmental Conservation

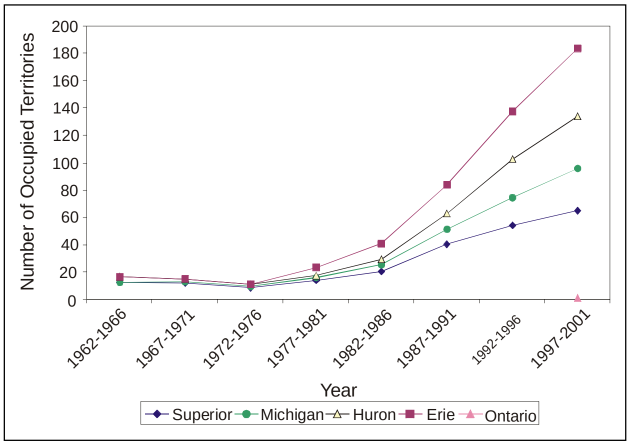

Figure 2. Average number of occupied territories per year by Lake.
Source: Dave Best, U.S. Fish and Wildlife Service; Pamela Martin, Canadian Wildlife Service; and Michael Meyer, Wisconsin Department of Natural Resources

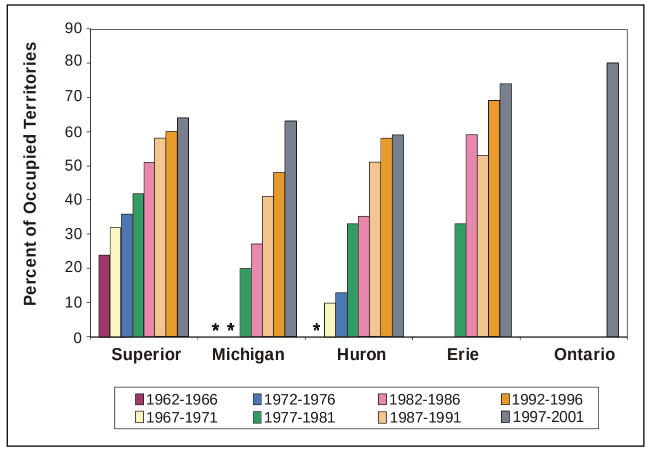

Figure 3. Average percentage of occupied territories fledging at least one young.
Source: Dave Best, U.S. Fish and Wildlife Service; Pamela Martin, Canadian Wildlife Service; and Michael Meyer, Wisconsin Department of Natural Resources

Ecosystem Objective
This indicator supports annexes 2, 12, and 17 of the Great Lakes Water Quality Agreement.

State of the Ecosystem
Concentrations of organochlorine chemicals are decreasing or stable but still above No Observable Adverse Effect Concentrations (NOAECs) for the primary organic contaminants, DDE and PCBs. Bald eagles are now distributed extensively along the shoreline of the Great Lakes (Figure 1).

The number of active bald eagle territories has increased markedly from the depths of the population decline caused by DDE (Figure 2). Similarly, the percentage of nests producing one or more fledglings (Figure 3) and the number of young produced per territory (Figure 4) have risen. The recovery of reproductive output at the population level has followed similar patterns in each of the Lakes, but the timing has differed between the various Lakes. Lake Superior recovered first, followed by Erie and Huron, and most recently, Lake Michigan. An active territory has been reported from Lake Ontario. Established territories in most areas are now producing one or more young per territory indicating that the population is healthy and capable of growing. Eleven developmental deformities have been reported in bald eagles within the Great Lakes watershed; five of these were from territories potentially influenced by the Great Lakes.

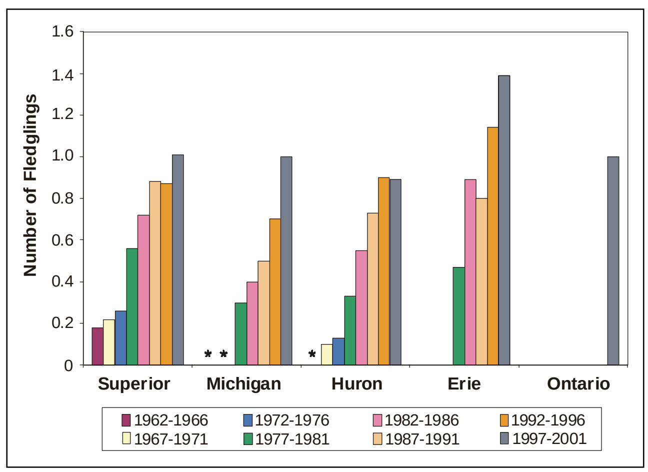

Figure 4. Average number of young fledged per occupied territory per year.
Source: Dave Best, U.S. Fish and Wildlife Service; Pamela Martin, Canadian Wildlife Service; and Michael Meyer, Wisconsin Department of Natural Resources

Future Pressures
High levels of persistent contaminants in bald eagles continue to be a concern for two reasons. Eagles are relatively rare and contaminant effects on individuals can be important to the well-being of local populations. In addition, relatively large areas of habitat are necessary to support eagles and continued development pressures along the shorelines of the Great Lakes constitute a concern. The interactions of contaminant pressures and habitat limitations are unknown at present. There

are still several long reaches of the Great Lakes shoreline, particularly around Lake Ontario, where the bald eagle has not recovered to its pre-DDE status.

Further Work Necessary
The health and contaminant status of bald eagles should continue to be monitored across the Great Lakes basin. A variety of groups continue to accomplish this work and provide compatible data for basinwide assessment. Two particular needs for additional data still exist. There is no basinwide effort directed toward assessing habitat suitability of shoreline areas for bald eagles. Further, it is not known to what degree the shoreline populations depend on recruiting surplus young from healthy inland populations to maintain the current growth rate or whether the shoreline populations are self-sustaining.

Acknowledgments
Authors: Ken Stromborg and David Best, U.S. Fish and Wildlife Service, East, and Pamela Martin, Canadian Wildlife Service.

Sources
Additional data were contributed by: Ted Armstrong, Ontario Ministry of Natural Resources; Lowell Tesky, Wisconsin Department of Natural Resources; Cheryl Dykstra, Cleves, OH; Peter Nye, New York Department of Environmental Conservation; William Bowerman, Clemson University. Lake Erie and Lake Superior LaMPs, John Netto, U.S. Fish & Wildlife Service assisted with computer support.

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Acid Rain

SOLEC Indicator #9000 - Indicator Matrix

Assessment: Mixed Improving

Purpose
To assess sulfate levels in precipitation and critical loadings of sulfate to the Great Lakes basin, and to infer the efficacy of policies to reduce sulfur and nitrogen oxide emissions to the atmosphere.

Ecosystem Objective
The 1991 Canada-U.S. Air Quality Agreement (Air Quality Agreement) pledges the two nations to reduce the emissions of acidifying compounds by approximately 40% relative to 1980 levels. The 1998 Canada-Wide Acid Rain Strategy for Post-2000 intends to further reduce emissions to the point where deposition containing these compounds does not adversely impact aquatic and terrestrial biotic systems.

State of the Ecosystem
Acid rain, more properly called "acidic deposition", is caused when two common air pollutants (sulfur dioxide–SO_2 and nitrogen oxides–NO_x) are released to the atmosphere, react and mix with high altitude water droplets and return to the earth as acidic rain, snow, fog or dust. These pollutants can be carried over long distances by prevailing winds, creating acidic precipitation far from the original source of the emissions. Environmental damage typically occurs where local soils and/or bedrock do not effectively neutralize the acid.

Lakes and rivers have been acidified by acid rain causing the disappearance of many fish species, invertebrates and plants. Not all lakes exposed to acid rain become acidified however. Lakes located in terrain that is rich in calcium carbonate (e.g. on limestone bedrock) are able to neutralize acidic deposition. Much of the acidic precipitation in North America falls in areas around and including the Great Lakes basin. Northern Lakes Huron, Superior and Michigan, their tributaries and associated small inland lakes are located on the geological feature known as the Canadian Shield. The Shield is primarily composed of granitic bedrock and glacially derived soils that cannot easily neutralize acid, thereby resulting in the acidification of many small

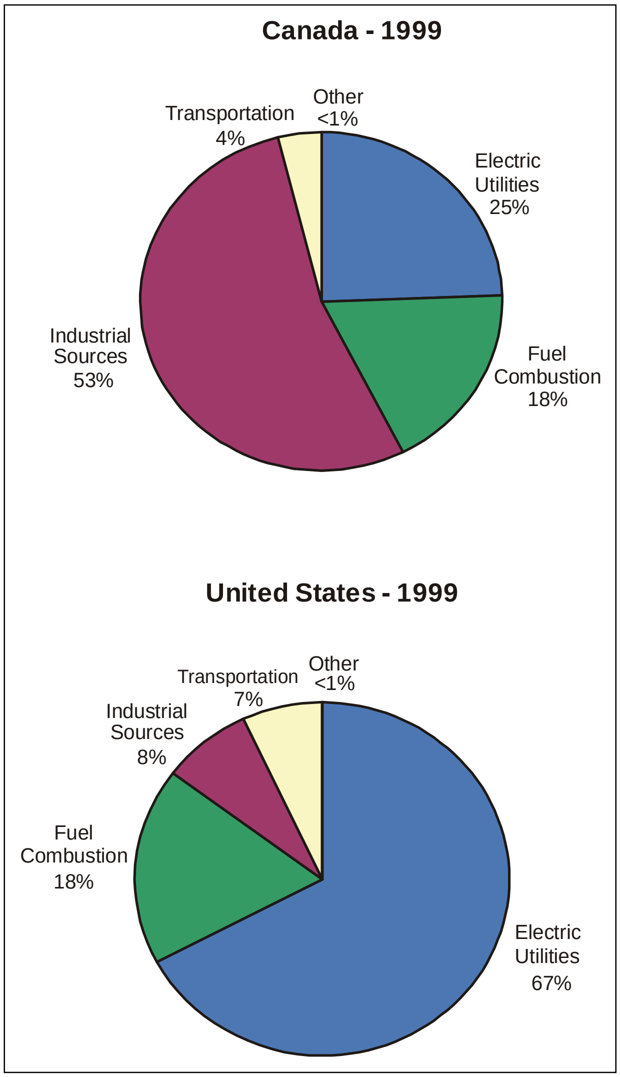

Figure 1. Sources of sulphur dioxide emissions in Canada and the U.S., 1999.
Source: Canada-United States Air Quality Agreement, Progress Report, 2002

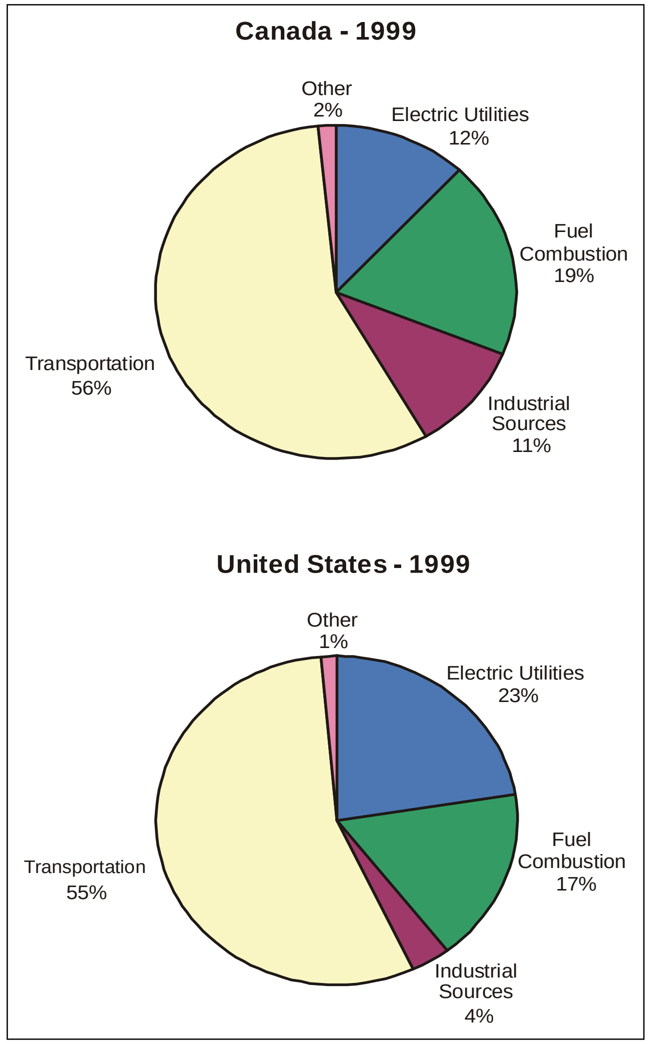

Figure 2. Sources of nitrogen oxide emissions in Canada and the U.S., 1999.
Source: Canada-United States Air Quality Agreement, Progress Report, 2002

lakes (particularly in northern Ontario and the northeastern United States). The five Great Lakes are so large that acidic deposition has little effect on them directly. Impacts are mainly felt on vegetation and inland lakes in acid-sensitive areas.

A recent report published by the Hubbard Brook Research Foundation has demonstrated that acid deposition is still a significant problem and has had a greater environmental impact than previously thought. For example, acid deposition has altered soils in the northeastern U.S. through accelerated leaching of base cations, accumulating concentrations of nitrogen and sulfur, and increasing concentrations of aluminum in soil waters. Acid deposition has also contributed to the decline of red spruce trees and sugar maple trees in the eastern U.S.

Sulfur Dioxide and Nitrous Oxides Emissions Reductions: SO_2 emissions come from a variety of sources. The most common releases of SO_2 in Canada are industrial processes such as non-ferrous mining and metal smelting. In the United States, electrical utilities constitute the largest emissions source (Figure 1). The primary source of NO_x emissions in both countries is the combustion of fuels in motor vehicles, with electric utilities and industrial sources also contributing (Figure 2).

Canada is committed to reducing acid rain in all parts of the country to levels below those that cause harm to ecosystems–a level commonly called the "critical load". In 2000, total SO2 emissions in Canada were 2.5 million tonnes, which is about 20 percent below the national cap of 3.2 million tonnes as established under Annex 1 (the Acid Rain Annex) of the Air Quality Agreement. Emissions in 2000 also represent a 45 percent reduction from 1980 emission levels. The seven easternmost provinces' 1.6 million tonnes of emissions in 2000 were 29 percent below the eastern Canada cap of 2.3 million tonnes as established under the Acid Rain Annex.

In 2001, all participating sources of the U.S. EPA's Acid Rain Program (Phase II) achieved a total reduction in SO_2 emissions of about 32 percent from 1990 levels, and 35 percent from 1980 levels. A total number of 3,065 units participated in the Acid Rain Program in 2001. These units reduced their SO_2 emissions to 10.63 million tons in 2001, 5 percent lower than 2000 emissions. Full implementation of the program in 2010 will achieve a 10 million ton reduction of SO_2 emissions, about 40 percent below 1980 levels. (For additional information on SO2 emission reductions, including sources outside the Acid Rain Program, please refer to the SOLEC Indicator Report #4176 Air Quality).

By 2000, Canadian NO_x emissions were reduced by more than 100,000 tonnes below the forecast level of 970,000 tonnes (established by Acid Rain Annex) at power plants, major combustion sources, and smelting operations. Canada is also developing other programs to further reduce NO_x emissions (For additional details, please refer to the SOLEC Indicator Report # 4176 Air Quality).

In the U.S., reductions in NOx emissions have significantly surpassed the 2 million ton reduction for stationary and mobile sources mandated by the Clean Air Act Amendments of 1990. Under the Acid Rain Program alone, NO_x emissions for the 2,626 affected sources in 2001 were 4.7 million tons, 30 percent lower than emissions in 1990. (For additional information on NO_x emission reductions, including sources outside the Acid Rain Program, please refer to the SOLEC Indicator Report # 4176 Air Quality).

Future Pressures

Figure 3 illustrates the trends in SO2 emission levels in Canada and the United States measured from 1980 to 2000 and predicted through 2010. U.S. levels dropped by 34 percent from 1980 to 2000. Canadian SO_2 emission levels decreased 45 percent from 1980 to 2000. Overall, a 38 percent reduction in SO2 emissions is projected in Canada and the United States from 1980 to 2010, mainly due to controls on electric utilities under the Acid Rain Program and the desulphurization of diesel fuel under Section 214 of the 1990 Clean Air Act Amendments in the U.S. In Canada, reductions of SO_2 are mainly attributed to reductions from the non-ferrous mining and smelting sector, and electric utilities as part of the Canada-Wide Acid Rain Strategy program. Despite these efforts, rain is still too acidic throughout most of the Great Lakes region.

Figure 4 illustrates the trends in NO_x emission levels in Canada and the United States measured from 1990 to 2000 and predicted through 2010. U.S. levels increased by approximately five percent from 1990 to 1999, but decreased by the same percentage from 1999 to 2000. In 2010, U.S. levels are expected to decrease by approximately 21 percent from 2000 levels. U.S. reductions in NO_x emissions are attributed to controls in electric utilities under the Acid Rain Program, the estimated controls associated with EPA's Regional Transport NO_x SIP Call, the Tier

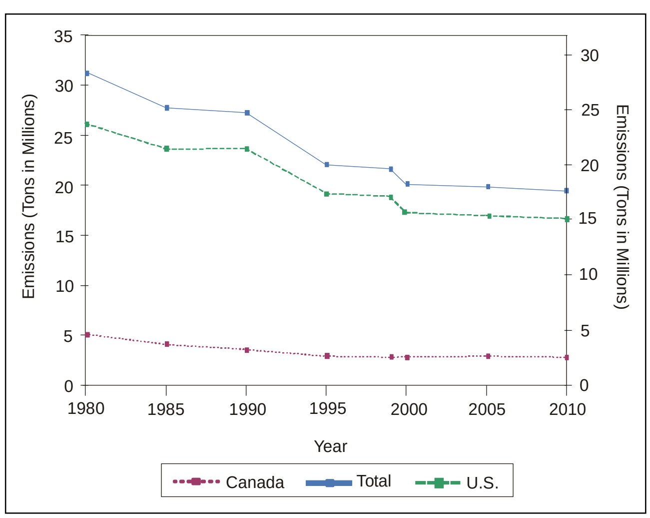

Figure 3. Canada – U.S. SO_2 emissions, 1980-2010.
Source: Canada-United States Air Quality Agreement, Progress Report, 2002

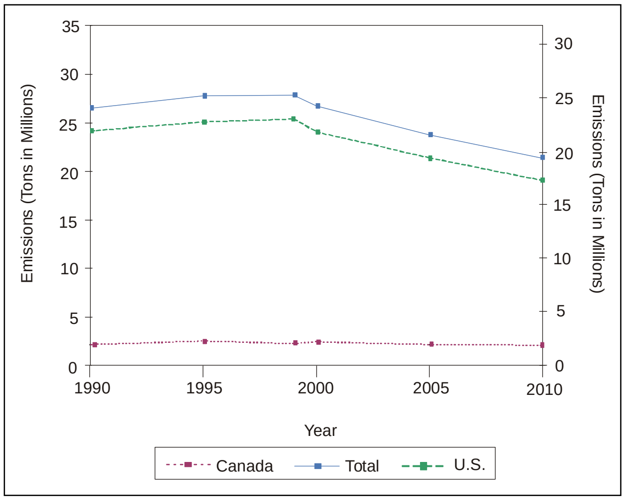

Figure 4. Canada – U.S. NO_x emissions, 1990-2010.
Source: Canada-United States Air Quality Agreement, Progress Report, 2002

2 Tailpipe Standard, and the Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Rulemaking. Canadian NOx emissions have increased slightly since 1990, but are expected to decrease to 1980 levels by 2010. These small reductions are also attributed to mobile sources.

Figure 5 compares wet sulfate deposition (kilograms sulfate per hectare per year) over eastern North America before and after the 1995 Acid Rain Program Phase I SO_2 emission reductions to assess whether the emission decreases have had an impact on large-scale wet deposition. The five-year average sulfate wet deposition pattern for the years 1996-2000 is considerably reduced from that for the five-year period prior to the Phase I emission reductions (1990-1994). For example, the large area that received 25 to 30 kg/ha/yr of sulfate wet deposition in the 1990-1994 period almost disappeared in 1996-2000 period. The shrinkage of the wet deposition pattern between the two periods strongly suggests that the Phase I emission reduction were successful at reducing the sulfate wet deposition over a large section of eastern North America. If SO_2 emissions remain relatively constant after the year 2000, as predicted (Figure 3), it is unlikely that sulfate deposition will change in the coming decade. Sulfate deposition models predict that in 2010, critical loads for aquatic ecosystems in eastern Canada will still be exceeded over an area of 800,000 to 1,200,000 km^2.

A somewhat different story occurs for nitrate wet deposition in that the spatial patterns shown in Figure 5 are approximately the same before and after the Phase I emission reductions. This suggests that the minimal reductions in NO_x emissions after Phase I resulted in minimal changes to nitrate wet deposition over eastern North America.

Pressures will continue to grow as the population within and outside the basin increases, causing increased demands on electrical utility companies, resources and an increased number of motor vehicles. Considering this, reducing nitrogen deposition is becoming more and more important, as its contribution to acidification may soon outweigh the benefits gained from reductions in sulfur dioxide emissions.

Future Activities
The effects of acid rain can be seen far from the source, so the governments of Canada and the United States are working together to reduce acid emissions.

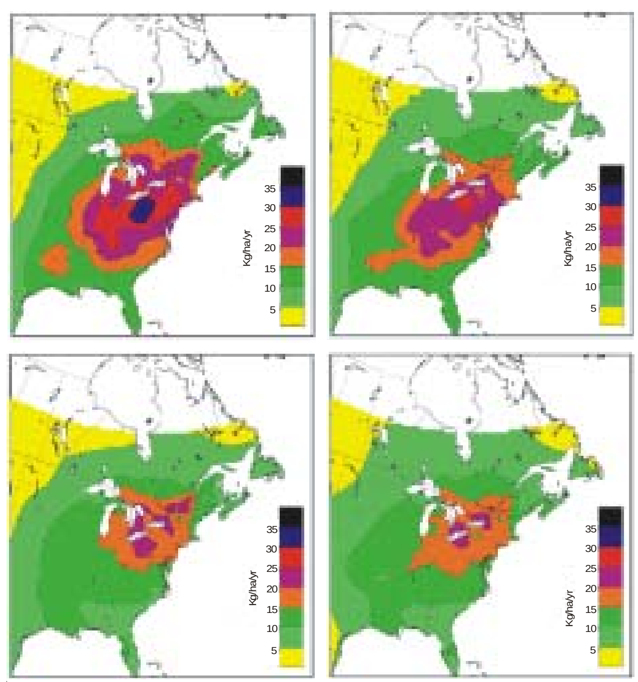

Figure 5. Patterns of wet non-sea salt SO_4 and wet NO_3 deposition for two five-year periods during the 1990s. (top left: SO_4 for 1990-1994; top right: SO_4 for 1996-2000; bottom left: NO_3 for 1990-1994; bottom right: NO_3 for 1996-2000).
Source: Canada-U.S. Air Quality Agreement 2002 Progress Report

The 1991 Canada-United States Air Quality Agreement addresses transboundary pollution. To date, this agreement has focused on acidifying pollutants and significant steps have been made in the reduction of SO_2 emissions. However, further progress in the reduction of acidifying pollutants is required.

In December 2000, Canada and the United States signed Annex III (the Ozone Annex) to the Air Quality Agreement. The Ozone Annex committed Canada and the U.S. to aggressive emission reduction measures to reduce emissions of NO_x and volatile organic compounds. (For more information on the Ozone Annex, please refer to the SOLEC Indicator Report # 4176 Air Quality).

The 1998 Canada-Wide Acid Rain Strategy for Post-2000 provides a framework for further actions, such as establishing new sulfur dioxide emission reduction targets in Ontario, Quebec, New Brunswick and Nova Scotia. In fulfillment of the Strategy, each of these provinces has announced a 50% reduction in its existing emissions cap. Quebec, New Brunswick and Nova Scotia are committed to achieving their caps by 2010, while Ontario committed to meet its new cap by 2015.

Since the last SOLEC Report, there has been increasing interest in both the public and private sector in a multi-pollutant approach to reducing air pollution. In February 2002, U.S. President George W. Bush proposed the Clear Skies Initiative, which would significantly reduce power plant emissions of SO_2, NO_x, and mercury. This initiative would establish national, enforceable emission caps for the three pollutants and would provide a cut in SO_2 emissions of 73 percent from 2000 emissions of 11 million tons and in NO_x emissions by 67 percent from 2000 emissions of 5 million tons by 2018.

Further Work Necessary

While North American SO_2 emissions and sulfate deposition levels in the Great Lakes basin have declined over the past 10 to 15 years, many acidified lakes do not show recovery (increase in water pH or alkalinity). Empirical evidence suggests that there are a number of factors acting to delay or limit the recovery response, e.g. increasing importance of nitrogen-based acidification, soil depletion of base cations, mobilization of stored sulfur, climatic influences, etc. Further work is needed to quantify the additional reduction in deposition needed to overcome these limitations and to accurately predict the recovery rate.

Acknowledgments

Authors: Dean S. Jeffries, National Water Research Institute, Environment Canada, Burlington, ON; Robert Vet, Meteorological Service of Canada, Environment Canada, Downsview, ON; and Todd Nettesheim, Great Lakes National Program Office, United States Environmental Protection Agency, Chicago, IL.

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Non-Native Species Introduced into the Great Lakes

SOLEC Indicator #9002 - Indicator Matrix

Assessment: Poor (aquatic portion)

Purpose

This indicator reports introductions of aquatic organisms not naturally occurring in the Great Lakes, and is used to assess the status of biotic communities in these freshwater ecosystems. Human activities associated with shipping, canals, deliberate release (authorized and not), and aquaculture are responsible for the bulk of non-indigenous species (NIS) present in the Great Lakes. Reporting new species will highlight the need for more effective safeguards to prevent the introduction and establishment of new NIS.

Ecosystem Objective

The purpose of the U.S. and Canada Water Quality Agreement is, in part, to restore and maintain the biological integrity of the waters of the Great Lakes ecosystem. Minimally, it is intended to prevent extinctions and unauthorized introductions. Nearly 10% of the NIS introduced in the Great Lakes have had a significant impact on ecosystem health, a percentage consistent with findings in the United Kingdom and the Hudson River of North America. In particular and most recently, live fish and invertebrates in ballast water discharges into the Great Lakes have been demonstrated to constitute a threat to the ecosystem.

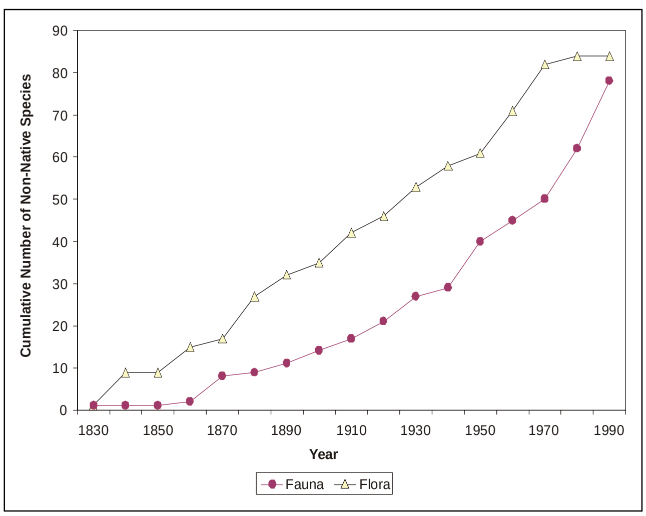

Figure 1. Cumulative number of aquatic non-native species established in the Great Lakes basin since the 1830s.
Source: Mills *et al.*, 1993, Ricciardi, 2001

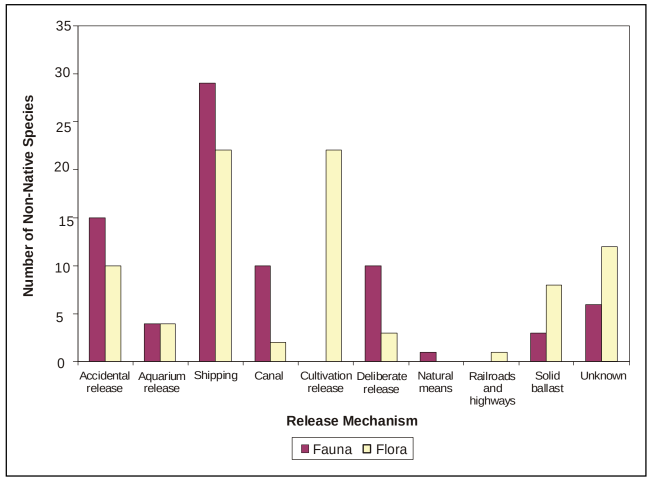

Figure 2. Release mechanisms for aquatic non-native species established in the Great Lakes basin since 1830.
Source: Mills *et al.*, 1993, Ricciardi, 2001

State of the Ecosystem

Numbers of NIS introduced and established in the Great Lakes have increased steadily since the 1830s (Figure 1). The identification of ship ballast water as a major vector transporting unwanted organisms into the Great Lakes (Figure 2) has motivated control efforts. In 1989, Canada introduced voluntary ballast exchange, as recommended by the International Joint Commission and Great Lakes Fishery Commission in the wake of Eurasian ruffe and zebra mussel introductions. In 1990, the United States Congress passed the Aquatic Nuisance Species Control and Prevention Act (followed by the Non-Indigenous Species Act) and by May of 1993, the first and only ballast management regulations in the world were adopted. Although ballast exchange programs have been implemented in Canada and the United States, new species associated with shipping activities continue to become established. Other non-native species, such as the European flounder, have been observed but have not become established.

Future Pressures

Non-native species have invaded the Great Lakes

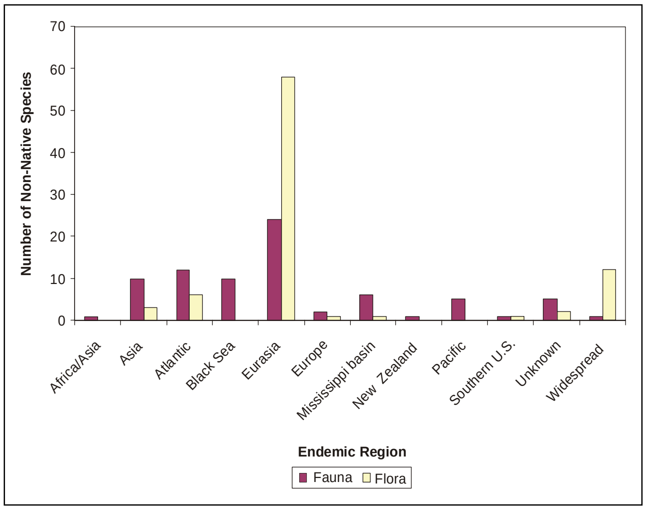

Figure 3. Regions of origin for aquatic non-native species established in the Great Lakes basin.
Source: Mills *et al.*, 1993, Ricciardi, 2001

basin from regions around the globe (Figure3), and increasing world trade will elevate the risk that new species will continue to gain access to these ecosystems. New diversions of water into the Great Lakes, and fast-growing aquaculture industries such as fish farming, live food, and garden ponds, will also increase the risk of new invasive species. Changes in water quality, temperature, and the previous NIS introductions may make the Great Lakes more hospitable for the establishment of new invaders.

Future Actions
Researchers are seeking to better understand the contributions of various vectors and donor regions, the receptivity of the Great Lakes ecosystem, and the biology of new invaders, in order to recommend improved safeguards that will reduce the invasion risk of new biological pollutants in the Great Lakes.

Further Work Necessary
To restore and maintain the biological integrity of the Great Lakes, it is essential that the routes of entry for non-native species be closely monitored, and effective safeguards introduced and adjusted as necessary.

Acknowledgments
Authors: Edward L. Mills and Kristen T. Holeck, Department of Natural Resources, Cornell University, Bridgeport, NY and Margaret Dochoda, Great Lakes Fishery Commission, Ann Arbor, MI.

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1.4 PRESSURE INDICATOR REPORTS-PART 2

SUMMARY OF PRESSURE INDICATORS-PART 2

The overall assessment for the State indicators is incomplete. Part One of this Assessment presents the indicators for which we have the most comprehensive and current basin-wide information. Data presented in Part Two of this report represent indicators for which information is not available year to year or are not basin-wide across jurisdictions. Within the Great Lakes indicator suite, 38 have yet to be reported, or require further development. In a few cases, indicator reports have been included that were prepared for SOLEC 2000, but that were not updated for SOLEC 2002. The information about those indicators is believed to be still valid, and therefore appropriate to be considered in the assessment of the Great Lakes. In other cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

Indicator Name	Assessment in 2000	Assessement in 2002
Contaminants in Young-of-the-Year Spottail Shiners	No Report	Mixed, improving
Toxic Chemical Concentrations in Offshore Waters	Mixed	Mixed, improving
Concetnrations of Contaminants in Sediment Cores	No Report	Mixed, improving
E.coli and Fecal Coliform Levels in Nearshore Recreational Waters	Mixed	Mixed
Drinking Water Quality	Good	Good
Contaminants in Snapping Turtle Eggs	Mixed	Mixed
Effect of Water Level Fluctuations	Mixed, deteriorating	Mixed
Mass Transporation	Not Assessed	Mixed
Water Use	Not Assessed	Mixed
Energy Consumption	No Report	Mixed, deteriorating (for Lake Superior basin)
Solid Waste Generation	No Report	Mixed
Population Monitoring and Contaminants Affecting the American Otter	Not Assessed	Mixed

Green represents an improvement of the indicator assessment from 2000.
Red represents deterioration of the indicator assessment from 2000.
Black represents no change in the indicator assessment from 2000, or where no previous assessment exists.

Contaminants in Young-of-the-Year Spottail Shiners

Indicator ID #114 - Indicator Matrix

Assessment: Mixed Improving

Purpose

Fish are an important indicator of contaminant levels in a system because of the bioaccumulation of organochlorine chemicals and metals in their tissues. Contaminants that are often undetectable in water may be detected in juvenile fish. Juvenile spottail shiner (*Notropis hudsonius*) was selected by Suns and Rees (1978) as the principal biomonitor for assessing trends in contaminant levels in nearshore waters. It is the preferred species for the following reasons: it has limited range in the first year of life; undifferentiated feeding habits in early stages; is important as a forage fish; and is present throughout the Great Lakes. The position it holds in the food chain also creates an important link for contaminant transfer to higher trophic levels.

Ecosystem Objective

To identify areas of concern and monitor contaminant trends over time for the near shore waters of the Great Lakes.

Concentrations of toxic contaminants in juvenile forage fish should not pose a risk to fish-eating wildlife. The International Joint Commission's Aquatic Life Guideline (GLWQA 1978) and the New York State Department of Environmental Conservation (NYSDEC) Fish Flesh Criteria (Newell *et al*., 1987) for the protection of piscivorous wildlife are used as acceptable guidelines for this indicator. Contaminants detected in forage fish and their respective guidelines are: polychlorinated biphenyls (PCBs), 100ng/g; dichlorodiphenyl trichloroethane and breakdown products (total DDT), 200ng/g; hexachlorocyclohexane, 100ng/g; hexachlorobenzene (HCB), 330ng/g; octachlorostyrene, 20ng/g; chlordane (500ng/g); and mirex (5ng/g). Since the mirex guideline is equal to the detection limit, if mirex is detected, the guideline is exceeded.

State of the Ecosystem

In each of the Great Lakes, PCB is the contaminant most frequently exceeding the guideline. Total DDT is often detected and although the guideline was exceeded in the past, currently concentrations are well below the guideline. Mirex is detected and exceeds the guideline only at Lake Ontario locations. Other PBT chemicals listed above are not frequently detected, and if detected, are at concentrations well below guidelines.

Lake Erie: Trends were examined for four locations in Lake Erie: Big Creek, Leamington, Grand River and Thunder Bay Beach. Overall, the trends show higher concentrations of PCBs in the early years with a steady decline over time. At Big Creek PCB concentrations were high until 1986, usually exceeding 300ng/g. After 1987, PCB concentrations have remained near the guideline of 100 ng/g. At the

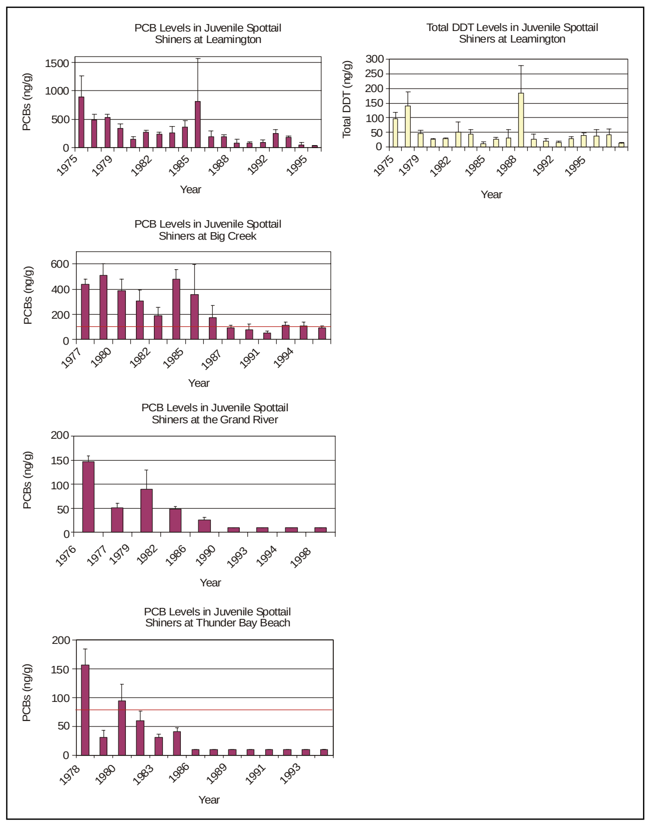


Figure 1. PCB and total DDT levels in juvenile spottail shiners from four locations in Lake Erie. The figures show mean concentration plus standard deviation. The red line indicates the wildlife protection guideline. When not detected, one half of the detection limit was used to calculate the mean concentration.

Source: Ontario Ministry of the Environment

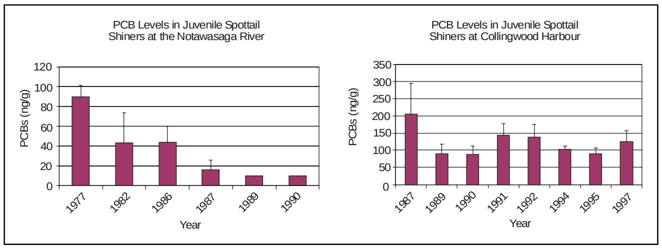


Figure 2. PCB levels in juvenile spottail shiners from two location in Lake Huron. The figures show mean concentration plus standard deviation of PCBs. When not detected, one half of the detection limit was used to calculate the mean concentration.
Source: Ontario Ministry of the Environment

Grand River, PCBs declined from a high of 146ng/g in 1976 to less than the detection limit (20n/g) in 1990. At Thunder Bay Beach the highest concentration of PCBs was in 1978 (146ng/g). After 1978, PCB concentrations have been less than the 100ng/g guideline.

Total DDT concentrations at Lake Erie sites have been well below the guideline except at Leamington where 183ng/g was reported in 1986. Maximum concentrations at other Lake Erie sites were found in the 1970s and ranged from 38ng/g at Thunder Bay Beach to 75ng/g at Big Creek.

Lake Huron: Trend data are available for two locations in Lake Huron: Collingwood Harbour and Nottawasaga River. At Collingwood Harbour the highest PCB concentrations were found when sampling commenced in 1987 (206ng/g). Since then, PCB concentrations have either exceeded or fallen just below the guideline. At the Nottawasaga River the highest concentration of PCBs was in 1977 (90ng/g). Concentrations declined to less than the detection limit by 1987. The highest concentration of total DDT at Collingwood Harbour was found in 1987 (24ng/g). At the Nottawasaga River, there has been a steady decline in total DDT since 1977 when concentrations were106ng/g.

Lake Superior: Trend data were examined for four locations in Lake Superior: Mission River, Nipigon Bay, Jackfish Bay and Kam River. Generally contaminant concentrations were low in all years and at all locations. The highest PCB concentrations in Lake Superior were found at the Mission River in

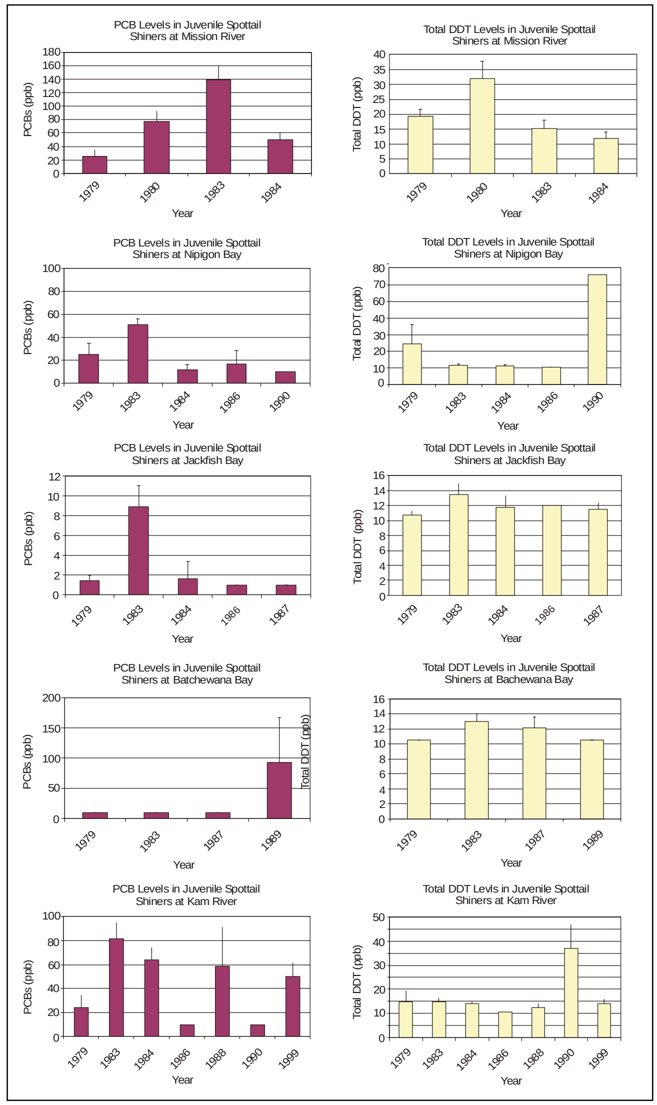
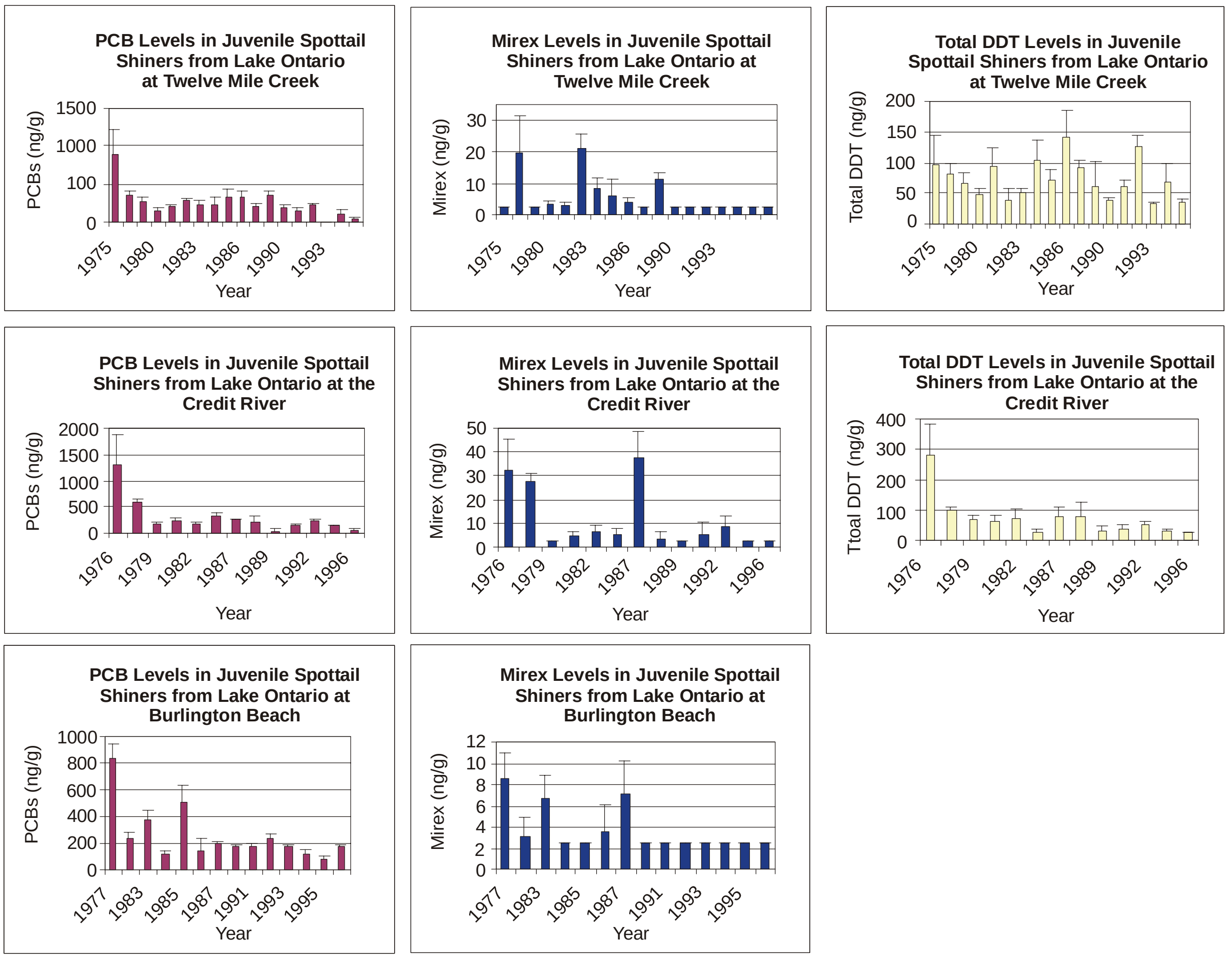


Figure 3. PCB and total DDT levels in juvenile spottail Shiners from five locations in Lake Superior. The figures show mean concentration plus standard deviation of PCBs and total DDT. When not detected, one half of the detection limit was used to calculate the mean concentration.
Source: Ontario Ministry of the Environment

1983 (139ng/g). All other analytical results were less than the guideline. Maximum concentrations for PCBs at the Lake Superior sites were from 1983 and ranged from 51ng/g at Nipigon Bay to 89ng/g at Jackfish Bay. The highest concentrations of DDT were found in 1990 at Nipigon Bay (66ng/g) and Kam River (37ng/g).



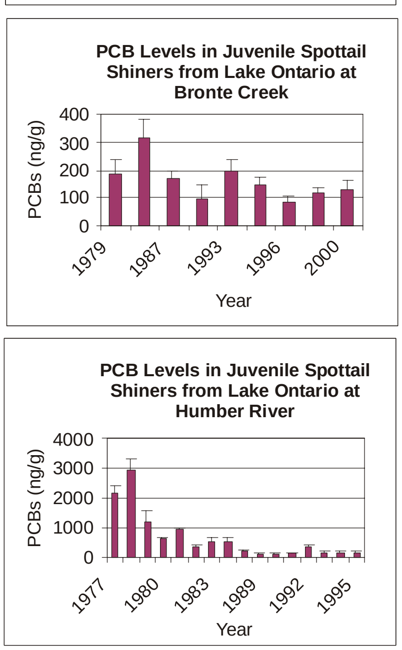


Figure 4. PCB, mirex, and total DDT levels in juvenile spottail shiners from five locations in Lake Ontario. The figures show mean concentration plus standard deviation of PCBs, total DDT and mirex. When not detected, one half of the detection limit was used to calculate the mean concentration.
Source: Ontario Ministry of the Environment

Lake Ontario: Contaminant concentrations from five locations were examined for trend analysis for Lake Ontario: Twelve Mile Creek, Burlington Beach, Bronte Creek, Credit River and the Humber River.

PCBs, total DDT and mirex are generally higher at these (and other Lake Ontario) locations than elsewhere in the Great Lakes. Overall, PCBs at all locations tended to be higher in the early years, ranging from 3 to 30 times the guideline. The highest concentrations of PCBs were found at the Humber River in 1978 (2938ng/g). In recent years PCBs have generally ranged from 100ng/g to 200ng/g.

Mirex has exceeded the guideline intermittently at all five locations. The maximum concentration was 37ng/g at the Credit River in 1992. Since 1992, mirex has not been detected at any of these locations.

Total DDT concentrations approached or exceeded the guideline at all five locations in the 1970s and on occasion in the 1980s. The maximum reported concentration was at the Humber River in 1978 when total DDT was 443ng/g. The typical concentration of total DDT at all five locations is currently near 50 ng/g.

Lake Michigan: No spottail shiners were sampled in Lake Michigan under this sport fish contaminant monitoring program.

Future Activities

Organochlorine contaminants have declined in juvenile fish throughout the Great Lakes. Regular monitoring should continue for all of these areas to determine if levels are below wildlife protection guidelines. Analytical methods should be improved to accommodate revised guidelines and to include additional contaminants such as dioxins and furans, dioxin-like PCBs and poly-brominanted diphenyl ethers. For Lake Superior, the historical data do not include toxaphene concentrations. Since this contaminant is responsible for most of the consumption advisories and restrictions on sport fish from this lake (Scheider *et al*., 1998), it is recommended that analysis of this contaminant be included in any future biomonitoring studies in Lake Superior.

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Toxic Chemical Concentrations in Offshore Waters

SOLEC Indicator #118 - Indicator Matrix

Assessment: Mixed Improving
Data are not system-wide.

Purpose
This indicator reports the concentration of priority toxic chemicals in offshore waters, and by comparison to criteria for the protection for aquatic life and human health infers the potential for impacts on the health of the Great Lakes aquatic ecosystem. As well, the indicator can be used to infer the progress of virtual elimination programs.

Ecosystem Objective
The Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life (GLWQA, Article III(d)).

State of the Ecosystem
Many toxic chemicals are present in the Great Lakes. As a result of various ecosystem health assessments, a comparatively small number have been identified as "critical pollutants". Even so, it is impractical to summarize the spatial and temporal trends of them all within a few pages.

Organochlorines, several of which are on various "critical pollutant" lists, have and are still declining in the Great Lakes in response to management efforts. Spatial concentration patterns illustrate the ubiquitous nature of some, or the influence of localized source(s) of others. An example of an organochlorine with more widespread distribution is dieldrin (Figure 1) which is observed at all open lake

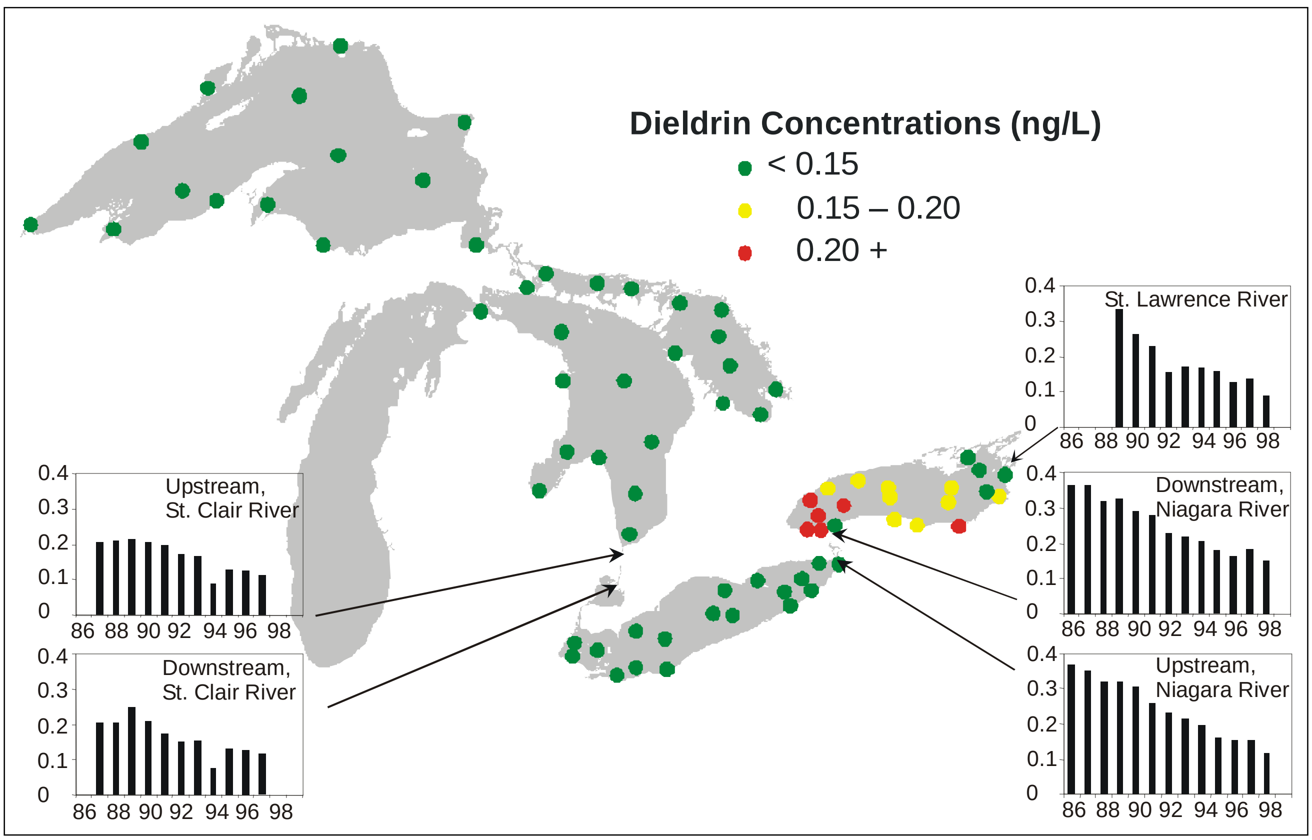

Figure 1. Spatial dieldrin patterns in the Great Lakes (Spring 1997, 1999, or 2000, Surface) and annual mean concentrations for the interconnecting channels from 1986 to 1998. Units = ng/L.
Source: Environmental Conservation Branch, Environment Canada

Chemical	Period of Record	Dissolved Phase	Particulate Phase
Chlorobenzenes			
1,2-dichlorobenzene	1986-1997	-62.6	-42.2
1,3-dichlorobenzene	1986-1997	-71.0	--
1,4-dichlorobenzene	1986-1997	-53.2	NS
1,2,3-trichlorobenzene	1986-1997	-61.6	-57.0
1,2,4-trichlorobenzene	1986-1997	-63.7	-61.0
1,3,5-trichlorobenzene	1986-1997	-52.5	NS
1,2,3,4-tetrachlorobenzene	-1997	-54.5	-75.1
Pentachlorobenzene	1986-1997	-57.5	-65.2
Hexachlorobenzene	1986-1997	-69.6	-51.0
Pesticides and PCBs			
ζ-BHC	1986-1997	-80.3	-68.1
ν-BHC	1986-1997	-51.5	--
ζ-Chlordane	1986-1997	NS	NS
ν-Chlordane	1986-1997	--	--
p,p'-DDT	1986-1997	--	-35.2
o,p'-DDT	1986-1997	--	--
p,p'-TDE	1986-1997	NS	-29.1
p,p'-DDE	1986-1997	NS	-23.2
Dieldrin	1986-1997	-56.5	-60.1
ζ-endosulfan	1986-1997	-48.2	--
η-endosulfan	1986-1997	--	--
Heptachlor-epoxide	1986-1997	-56.0	--
Mirex	1986-1997	--	-49.6
PCBs	1986-1997	-59.0	-75.5
PAHs			
Acenaphthylene	1989-1997	-42.3	--
Anthracene	1990-1997	NS	-43.4
Benz(a)anthracene	1986-1997	-40.8	-33.8
Benzo(a)pyrene	1988-1997	--	NS
Benzo(b/k)fluoranthene	1986-1997	NS	NS
Benzo(ghi)perylene	1989-1997	--	+205.9
Chrysene/triphenylene	1986-1997	NS	-22.0
Dibenz(a,h)anthracene	1990-1997	--	--
Fluoranthene	1986-1997	+272.0	+35.9
Fluorene	1989-1997	NS	--
Indenopyrene	1989-1997	--	+219.5
1-methylnaphthalene	1990-1997	-53.0	--
2-methylnaphthalene	1990-1997	NS	--
Naphthalene	1990-1997	NS	--
Phenanthrene	1989-1997	+36.0	-25.0
Pyrene	1986-1997	+239.8	+28.1
Industrial By products			
Hexachlorobutadiene	1986-1997	-64.0	-64.9
Octachlorobutadiene	1989-1997	--	-89.6
Hexachlorocyclopentadiene	1989-1997	-84.6	--

Figure 2. Percent composition change at Niagara-on-the-Lake. NS = no significant trend, '--' = too few values above the detection limit.

Source: Environmental Conservation Branch, Environment Canada stations and connecting channels sites. Concentrations throughout the Great Lakes have decreased by more than 50% between 1986 and 2000 and are still declining. However, dieldrin exceeds New York State's water quality criterion for the protection of human consumers of fish by a factor of 50-300 times.

Hexachlorobenzene (HCB), octachlorostyrene, and mirex exemplify organochlorines whose presence is due to historical, localized sources. Consequently, their occurrence in the environment is isolated to specific locations in the Great Lakes basin. Concentrations of all three in the Niagara River have decreased by more than 50% between 1986 and 1998. Both HCB and mirex continue to exceed New York State's criteria for the protection of human consumers of fish by a factor of 2 and 7, respectively.

Figure 2 illustrates the percentage change in concentration in dissolved phase and particulate phase samples collected at the mouth of the Niagara River during the period 1986 to 1997. Most chlorobenzenes, chlorinated pesticides and PCBs have decreased in concentration. For PAHs, some have decreased, some have not changed and a few have increased.

Future Pressures

Management efforts to control inputs of organochlorines have resulted in decreasing concentrations in the Great Lakes, however, historical sources for some still appear to affect ambient concentrations in the environment. The increase in some PAH concentrations in localized areas should be reviewed and analyzed in more detail. The ecosystem impact is unknown. Chemicals such as endocrine disrupting chemicals, in-use pesticides, and pharmaceuticals are emerging issues.

Future Actions

The Great Lakes Binational Toxics Strategy efforts need to be maintained to identify and track the remaining sources and explore opportunities to accelerate their elimination.

Targeted monitoring to identify and track down local sources should be considered for those chemicals whose distribution suggests localized influences.

The research community in the Great Lakes basin is actively pursuing the emerging chemicals issue. The monitoring community will need to incorporate these results in planning future monitoring programs.

Further Work Necessary

Environment Canada conducts routine toxic contaminant monitoring in the shared waters of the Great Lakes. However, a coordinated binational monitoring program is required with agreement on specifics such as frequency, analytical and field methodologies, and sampling locations. An agreed upon approach for summarizing and reporting the indicator will also be required given that many chemicals and locations have unique stories to tell.

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Concentrations of Contaminants in Sediment Cores

SOLEC Indicator #119 - Indicator Matrix

Assessment: Mixed Improving
Data are not system-wide.

Purpose
This indicator analyzes the concentration of toxic chemicals in sediments from two perspectives:

1. by comparing contaminant concentrations to available sediment quality guidelines, we can infer potential harm to aquatic ecosystems from contaminated sediments; and
2. using contaminant concentration profiles in sediment cores from open lake and, where appropriate, Areas of Concern index stations, we can infer progress towards virtual elimination of toxics in the Great Lakes.

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

Index
A sediment quality index (SQI) was developed from the metrics used in the recently approved Canadian Water Quality Index. The SQI was calculated according to an equation incorporating three elements; scope–the % of variables that did not meet guidelines; frequency–the % of failed tests relative to the total number of tests in a group of sites, and; amplitude–the magnitude by which the failed variables exceeded guidelines. A modified SQI was also developed, using only the scope and amplitude elements, which computed the SQI score per site with no grouping of sites. A full explanation of the SQI derivation process and a possible classification scheme based on the SQI score (0–100, poor to excellent) is provided in Grapentine *et al*. (In Press).

State of the Ecosystem
Environment Canada initiated a comprehensive sediment contaminant survey of the open waters of the Great Lakes in 1997. Data for 34 chemicals with guidelines were available for Lakes Erie and Ontario. Generally, the Canadian federal probable effect level (PEL) guideline (CCME, 2001) was used when available, otherwise the Ontario lowest effect level (LEL) guideline (Persaud *et al*., 1992) was used. The SQI ranged from fair in Lake Ontario to excellent in eastern Lake Erie (Figure 1). Spatial trends in sediment quality in Lakes Erie and Ontario reflected overall trends for individual contaminant classes such as mercury and polychlorinated biphenyls. The spatial representation of sediment quality using the individual site SQI scores as well as the area SQI scores represent the individual spatial patterns in the 34 chemicals.

Lake and Basin	SQI
Erie	
Western Basin	85
Central Basin	86
Eastern Basin	95
Ontario	
Niagara	67
Mississauga	66
Rochester	70
Kingston	87

Figure 1. SQI for Lakes Erie and Ontario.
Source: Painter, S. *et al*., 2001; Marvin, C.H. *et al*., 2002

The USEPA-GLNPO used the SQI to evaluate data collected as part of their investigation of contaminated sediments in nearshore areas and rivers within the Areas of Concern. The SQI was applied to 5 priority AOCs for which the USEPA has collected sediment data. Figure 2 contains the SQI scores for these 5 priority AOCs. SQI scores for these AOCs are based on the results of available chemical analysis for surficial sediment concentrations only. Future sediment data collected at these sites can be

Site	SQI Score
Grand Calumet River/Indiana Harbor, IN	24.5
Saginaw River and Harbor, MI	57.5
Buffalo River, NY	93.2
Sheboygan River and Harbor, WI	29.4
Ashtabula River and Harbor, OH	36.4

Figure 2. SQI scores for 5 U.S. priority AOC sediment assessments, data collected from 1987-1989.
Source: Scott Cieniawski, U.S. EPA

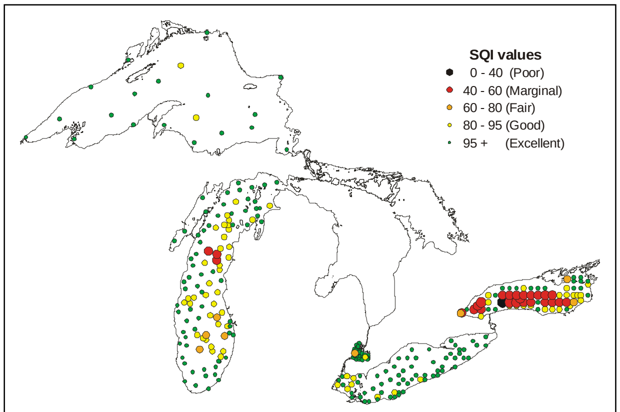

Figure 3. Site Sediment Quality Index (SQI) based on lead, zinc, copper, cadmium and mercury.
Source: Chris Marvin, Environment Canada, National Water Research Institute (1997-2001 data for all Lakes except Michigan); and Ronald Rossman, USEPA (1994-1996 data for Lake Michigan)

Chemical	Lake Ontario	Lake Erie (Western Basin)	Lake St. Clair
Mercury	73	37	N/A
Lead	30	40	N/A
PCBs	38	40	49
HCB	38	N/A	49
Dieldrin	19	+	+
Chordane	20	N/A	-
DDT	60	42	78
Toxaphene	N/A	+	N/A
Dioxins	70	N/A	N/A
PAHs	N/A	38	N/A

Figure 4. Percent Reduction in Concentrations at Open Lake Index Sites.
Source: Painter, S. *et al.*, 2001; Marvin, C.H. *et al.*, 2002

compared to these SQI scores to determine trends in sediment contamination.

Environment Canada and USEPA integrated available data from each of the open waters of the Great Lakes. To date, data on lead, zinc, copper, cadmium, and mercury have been integrated. Figure 3 illustrates the site by site SQI for Great Lakes sediments based on these metals.

Environment Canada analyzed the open lake sediment data to identify trends in sediment contamination at open lake index sites. Figure 4 illustrates the percent reduction in contaminant concentrations from cores at these index stations. In most cases, the declines in concentrations are in the range of 40%-50%.

Future Pressures

Management efforts to control inputs of historical contaminants have resulted in decreasing contaminant concentrations in the Great Lakes open-water sediments for the standard list of chemicals. However, additional chemicals such as polybrominated diphenyl ethers (PDBEs), polychlorinated naphthalenes (PCNs), polychlorinated alkanes (PCAs), endocrine disrupting chemicals, and in-use pesticides and pharmaceuticals represent emerging issues, and potential future stressors to the ecosystem.

Future Actions

Binational Toxics Strategy needs to be maintained to identify and track the remaining sources of contamination and to explore opportunities to accelerate their elimination.

1. Targeted monitoring to identify and track down local sources of pollution should be considered for those chemicals whose distribution in the ambient environment suggests localized sources.
2. The research community in the Great Lakes basin should continue to actively pursue the emerging chemicals issues. The monitoring community should incorporate the results of this research in the planning and implementation of future monitoring programs in the Great Lakes Basin.

Further Work Necessary

1. Environment Canada, Ontario Ministry of the Environment, and the USEPA need to determine the availability of historical and current sediment quality data (both near-shore and open lake) to facilitate both spatial analysis AND to confirm the availability of Index sites to examine temporal trends.
2. Continued exploration and refinement of the SQI approach should be explored, especially the issue of agreement on guidelines to use in implementing the SQI and an appropriate classification scheme.

Acknowledgments
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E.coli and Fecal Coliform Levels in Nearshore Recreational Waters

SOLEC Indicator #4081 - Indicator Matrix

Assessment: Mixed
Data are not system-wide and multiple data sources are not consistent.

Purpose
To assess *E. coli* and fecal coliform levels, which act as a surrogate indicator for other pathogen types, in nearshore recreational waters in order to infer potential harm to human health through body contact with nearshore recreational waters.

Ecosystem Objective
Waters used for recreational activities involving body contact should be substantially free from pathogens, including bacteria, parasites, and viruses, that may harm human health. As the surrogate indicator, *E. coli* and fecal coliform levels should not exceed national, state, and/or provincial standards set for recreational waters. The Ontario provincial standard currently in use is a maximum count of 100 *E. coli* per 100 mL (Ministry of Health, 1998). US EPA's bacteria criteria recommendations for *E. coli* are a geometric mean of 126 colony forming units (cfu) per 100 mL (US EPA, 1986) or 235 cfu per 100 mL as a single sample maximum. When high levels of these indicator organisms are detected, swimming at beaches is closed or advisories are issued to protect swimmers. This indicator supports Annexes 1, 2 and 13 of the GLWQA.

State of the Ecosystem
One of the most important factors in nearshore recreational water quality is that bacterial levels be at a level that will be safe for the public. Recreational waters may become contaminated with animal and human feces from sources and conditions such as combined sewer overflows (CSOs) and Sanitary Sewer Overflows (SSOs) that occur in certain areas after heavy rains, agricultural run-off, and poorly treated sewage. The trends provided by this indicator will aid in beach management and in the prediction of episodes of poor water quality. In addition, states are identifying point and non-point sources of pollution at their beaches, which will help identify why beach closings are occurring and possibly

identify remediation measures that can be taken to reduce the number of closings and advisories.

Trends: Figure 1 shows that for both the U.S. and Canada as the frequency in monitoring and reporting increases, more advisories and closings are also observed, especially after 1999. In fact, both countries experienced a doubling of beaches that had advisories or closings for more than 10% of the season in 2000. Further analysis of the data may show seasonal and local trends in recreational water. If episodes of poor recreational water quality can be associated with specific events, then forecasting for episodes of poor water quality may become more accurate. Thus far it has been observed in the Great Lakes basin that unless new contaminant sources are removed or introduced, beaches tend to respond with similar bacteria levels after events with similar precipitation and meteorological conditions.

There may be new indicators and new detection methods available in the near future through current research efforts occurring binationally in both public and private sectors, and academia. Although currently a concern in recreational waters, viruses and parasites are difficult to isolate and quantify, and feasible measurement techniques have yet to be developed. Comparisons of the frequency of beach closings and advisories are typically limited due to use of different water quality criteria in different localities. Conditions required to post Canadian beaches have become more standardized due to the 1998 Beach Management Protocol, but the conditions required to remove the postings remain variable. In the U.S., all coastal states intend to adopt *E. coli* indicators for fresh water as a condition of the BEACH Act grant by April, 2004.

Figure 2 illustrates how reporting is evolving from comparing assigned beach advisories or closings towards comparing actual exceedances of geometric mean standards. The method of issuing beach advisories is sometimes imperfect. When bacterial counts are above the standard, this information is not known until one or two days later when the lab results arrive. This process may leave a potentially contaminated beach open, risking swimmers' health, and may result in an advisory being issued when the problem has likely passed. Methods are needed to identify risk before exposure takes place. An examination of historical geometric means may provide a less subjective means of determining the health risk category of beaches.

Future Pressures

Additional point and non-point source pollution at coastal areas due to population growth and increased land use may result in additional beach closings and advisories. Inability to develop a rapid test protocol for *E. coli* is lending support to advanced models to predict when to post beaches.

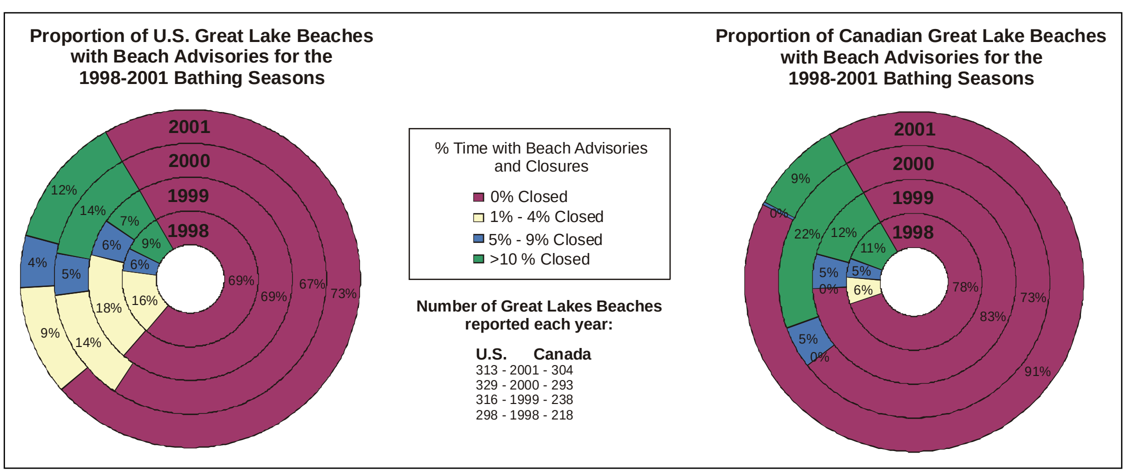

Figure 1. Proportion of U.S. and Canadian Great Lakes beaches with beach advisories and closures for 1998 to 2001 bathing seasons.

Source: Adapted from U.S. EPA Beach Watch Program, National Health Protection Survey of Beaches for Swimming, 1998 – 2001, and Canadian data obtained from Ontario Health Unites along the Great Lakes

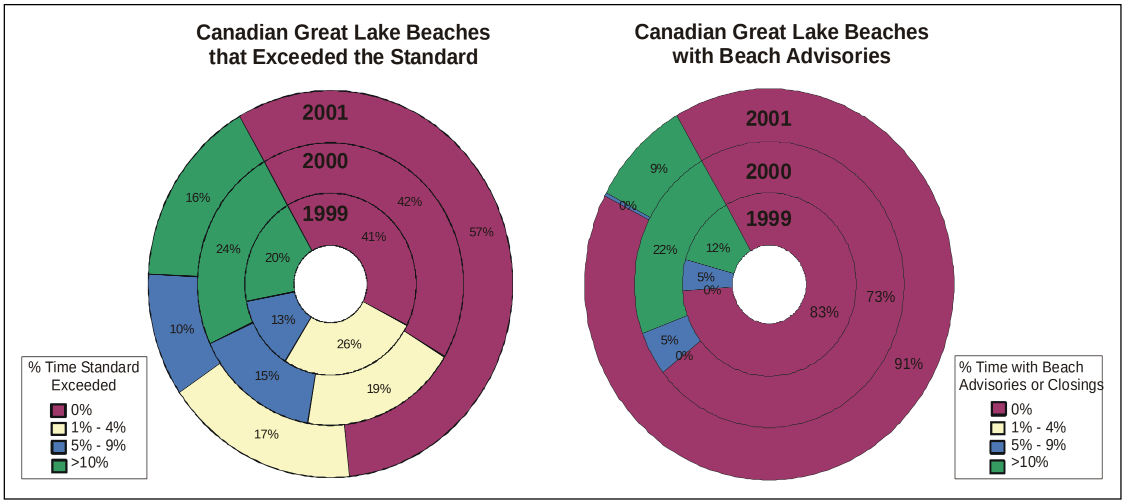

Figure 2. Status of Canadian Great Lakes beaches reported in terms of Beach Advisories versus Provincial Standard Exceedances (for the 1999 to 2001 bathing seasons).
Source: Data obtained from Ontario Health Units along the Great Lakes

Future Activities
Wet weather sources of pollution have the potential to carry pathogenic organisms to waters used for recreation and contaminate them beyond the point of safe use. USEPA is providing administrative, technical and financial support to state and local agencies to assist in the identification and remediation of pollution sources at high use beaches that are affected by CSOs, SSOs, and stormwater. Also, many municipalities are in the process of developing long-term control plans to address wet weather impacts.

The Great Lakes Strategy 2002 (http://www.epa.gov/glnpo/gls/index.html) envisions that all Great Lakes beaches will be swimmable and sets a goal that by 2010, 90% of monitored, high priority Great Lakes beaches will meet bacteria standards more than 95% of the swimming season. To help meet this goal, USEPA will build local capacity in monitoring, assessment and information dissemination to help beach managers and public health officials meet reccomendations contained in with U.S. EPA's National Beach Guidance (U.S. EPA July, 2002) at 95% of high priority coastal beaches.

Creating wetlands around rivers or areas of wet weather sources of pollution may help lower the levels of bacteria that cause beaches to be closed or advisories issued. The wetland area may reduce high bacterial levels that are typical after storm events by detaining and treating water in surface areas rather than releasing the bacteria rich waters into the local lakes and recreational areas. Studies by the Lake Michigan Ecological Research Station show that wetlands could lower bacterial levels at State Park beaches, but more work is needed (Mitchell, 2002).

Further Work Necessary
Variability in the data from year to year may result from changing seasonal weather conditions, the process of monitoring and variations in reporting, and may not be solely attributable to actual increases or decreases in levels of microbial contaminants. At this time, not all beaches are monitored in the Great Lakes basin, but most public coastal beaches in the U.S. will be monitored as a condition of the BEACH Act grants. Another BEACH Act grant condition is that recipients submit complete beach monitoring and advisory/closure data to the USEPA annually. In Canada there are plans to develop a web based data entry system to increase the efficiency and accuracy of the data collection and reporting system. The State of Michigan has an online site (http://www.glin.net/beachcast) where beach monitoring data is posted by Michigan beach managers.

Due to the nature of the lab analysis, each set of beach water samples requires an average of 1 to 2 days before the results are communicated to the health unit beach manager. To ensure accurate posting of Great Lakes beaches, methods must be developed to deliver quicker results. This issue may be addressed in the near future, as the BEACH Act requires USEPA to study issues associated with pathogens and human health and to publish new or revised Clean Water Act Section 304(a) criteria. U.S. EPA's National Health & Environmental Effects Reseach Laboratory (NHEERL) in Research Triangle Park, North Carolina, is evaluating methods for rapidly detecting recreational water quality and NHEERL and the Centers for Diesease Control and Prevention are carrying out epidemiological studies that relate swimming-associated illnesses to water quality. The information developed will be used by U.S. EPA's Office of Water to develop monitoring guidance. NHEERL conducted a pilot study at a Lake Michigan beach in 2002 and has begun implementing the studies this year at 2 Great Lakes beaches and will continue the studies at coastal freshwater and marine beaches through 2005. Until new indicators are available, predictive models and/or the experience of knowledgeable environmental or public health officers (who regularly collect the samples) can be used. Each method takes a variety of factors into account, such as amount of rainfall, cloud coverage, wind, current, point and non-point source inputs, presence of wildlife, to predict whether it is likely that *E. coli* or fecal coliform levels will be exceeded.

Acknowledgments

Authors: Christina Clark, Environment Canada intern, Downsview, ON, David Rockwell and Martha Aviles-Quintero Environmental Protection Agency-Great Lakes National Program Office, Chicago, IL and Holiday Wirick, Environmental Protection Agency Region 5 - Water Division, Chicago, IL

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Drinking Water Quality

SOLEC Indicator #4175 - Indicator Matrix

Assessment: Good

Data from multiple data sources are not consistent.

Purpose

The purpose of this indicator is to assess the chemical and microbial contaminant levels in drinking water and drinking water sources, and to evaluate the potential for human exposure to drinking water contaminants and the efficacy of policies and technologies to ensure safe drinking water.

Ecosystem Objective

The desired objective is that all treated drinking water should be safe to drink and be free from chemical and microbiological contaminants, supporting Annexes 1, 2, 12 and 16 of the Great Lakes Water Quality Agreement. To ensure safe drinking water and minimal potential health risks, it is important to include raw (or source) water as part of the assessment. Lower contaminant levels in raw water indicate a healthier ecosystem, and fewer health associated risks for humans.

State of the Ecosystem

Similar to SOLEC 2000, this indicator's evaluation is based on ten parameters. The chemical elements considered are atrazine, nitrate, and nitrite. The microbiological elements are total coliform, *Escherischia coli* (*E. coli*), *Giardia*, and *Cryptosporidium*. Turbidity, and total organic carbon (TOC)/dissolved organic carbon (DOC), while not necessarily health hazards in themselves, can be used to indicate other potential health problems that may arise. Finally, taste and odor are included because of their importance to consumers. Unlike 2000, this indicator has expanded to include raw, treated, and occasionally distributed samples from lake, river, and ground water sources. The map provided shows the locations of the public water systems (PWSs) and also the source from which the water is drawn. All analyses in this report are based on information provided by 114 PWSs for the years 1999 to 2001 and a review of the U.S. Safe Drinking Water Information

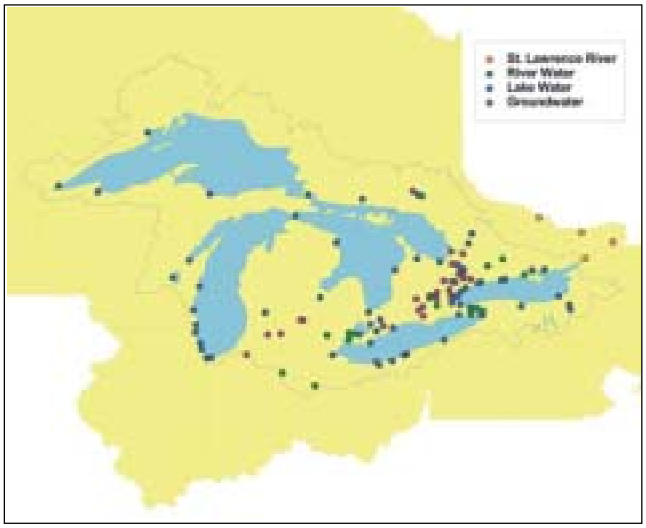

Figure 1. Locations of the public water systems (PWS) and the source from which the water is drawn.
Source: Mike Makdisi, U.S. Environmental Protection Agency Intern

System (SDWIS).

The risk for human exposure to chemical contaminants is minimal, based on atrazine data from 104 PWSs, and nitrate and nitrite data from 56 PWSs. Average and maximum levels for all three chemicals rarely exceeded the limits in treated drinking water, and most facilities' source water had levels so low that treatment was not needed to ensure compliance with the set standards. No violations occurred in treated water for atrazine, and only one water treatment plant (WTP) violated standards for nitrate. However small, a potential risk for exposure exists. Examination of the raw water showed that 8 samples, taken at two river WTPs and two lake WTPs, had elevated levels of atrazine in source water. On one occasion at a river WTP and on one occasion at a lake WTP, the elevated level of atrazine persisted after treatment. High levels of nitrate and nitrite were only found in raw water only during the months of May and June. Three WTPs had source water levels high enough to require treatment. Two of the three use ground water sources and one uses a Great Lakes connecting river.

By themselves, TOC and DOC do not necessarily threaten human health. They can, however, indicate the quality of source water and the potential for disinfectant chemicals such as chlorine to combine with organic carbon to form harmful byproducts during treatment. Both the province of Ontario and the U.S. Environmental Protection Agency have established TOC or DOC objectives or standards, along with proper treatment procedures, to keep taste and odor levels, partially caused by TOC/DOC, low, and to keep harmful byproducts, produced during disinfection, at safe levels.

Based on the 98 PWSs that provided information, TOC/DOC levels are usually higher in inland lakes and rivers, regardless of the season, with occasional elevated levels, scattered throughout the year, found in the Great Lakes and their connecting channels. Trends also indicate that WTPs across the basin are keeping their TOC/DOC levels relatively low after treatment. According to the data reported, almost 36% of the PWSs needed to treat their water for TOC/DOC at one point or another in order to meet the stated goals, but almost every elevated sample was reduced significantly during purification, as the graph demonstrates. The graph compares samples taken from water before treatment to the same water after treatment from various WTPs from around the basin. Based on these trends and results, it is clear that our technology is sufficient to keep TOC/DOC levels low, and assuming the disinfection process is managed properly, the relative risk of human exposure to harmful byproducts is low.

Taste and odor are very important to the consumer, but are also very difficult to analyze quantitatively. While the U.S. has a secondary standard (a non-enforceable guideline regulating contaminants that may cause cosmetic or aesthetic effects) of 3 TON (Threshold Odor Number), different ways of testing occur all throughout the basin. Neither standardized measurements, nor monitoring is required in the U.S. or Canada.

Since taste and odor problems are often associated with warmer waters, it is expected that higher levels of Geosmin and 2-MIB (chemicals indicative of taste and odor, which are also associated with algae blooms) would be found in the late summer and early fall. During 1999 to 2001, this pattern appeared in samples taken from the Great Lakes surface water, yet even these samples indicated few taste and odor problems. In contrast to Great Lakes surface water, elevated levels of Geosmin and 2-MIB were found during other times of the year in river water, and

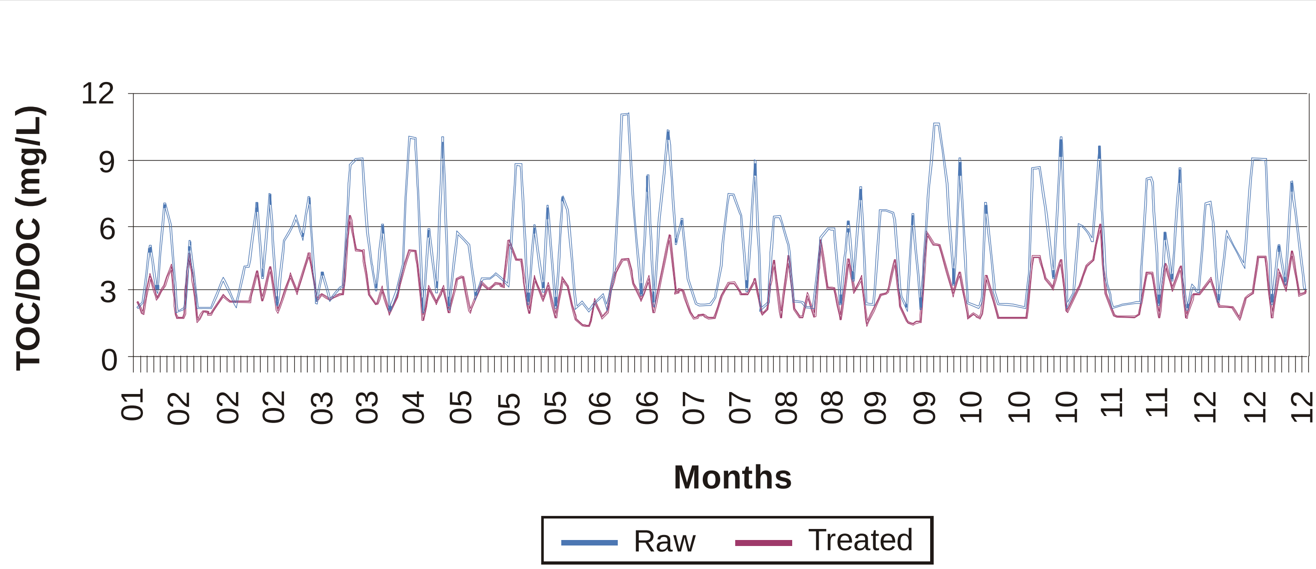

Figure 2. Raw and treated total organic carbon and total dissolved organic carbon, 2000.
Source: WTPs across Ontario and the United States

once in ground water. The most notable time was during the spring and early summer of 2000.

Overall, based primarily on samples before distribution, there were infrequent problems with taste and odor in drinking water from the Great Lakes basin. The TON standard was rarely exceeded when monitored, and few complaints from consumers were reported. Of the 60 WTPs that tested Geosmin and MIB in treated water, over two-thirds had drinking water that was always free from taste and odor problems.

Turbidity is important for the assessment of water quality. In raw water, it can disrupt the disinfecting efficiency of the treatment process, hide potential microorganisms, interfere with the filtration process, and may consist of toxic particles or particles that adsorb or bond with toxic substances. In treated water, it can act as an indicator of the efficiency of the drinking water treatment process.

The trend for turbidity from 1999-2001 shows that, for the most part, the turbidity levels for source water from the Great Lakes is declining, as demonstrated by the graph. The most turbid source water samples are from the Great Lakes, it's connecting rivers, and inland rivers, while inland lakes and ground water sources have lower levels. The established maximum acceptable concentration for treated drinking water in any one given sample for Ontario is 1.0 NTU (Nephelometric turbidity unit), and 5.0 NTU for the U.S. Only 7 samples were found in 4 WTPs in Ontario that exceeded this standard, and no exceedences were found in the US. Additional standards apply to U.S. WTPs for average monthly turbidity levels. A review of violations from the U.S. SDWIS database showed that only two PWSs may have violated these turbidity standards, but because the type of violation reported could have been caused by other factors, turbidity violations were not confirmed for this report. Overall, the WTPs within the Great Lakes basin rarely have problems with turbidity in drinking water by consistently reducing source water turbidity levels with treatment by several orders of magnitude. This demonstrates the effectiveness of our current technologies.

Based on data provided by 48 WTPs, the trend for total coliform and *E. coli* from 1999-2001 shows that higher coliform counts are found in the Great Lakes surface waters and rivers, with the highest counts occurring during the spring, summer and early fall. In addition, higher coliform counts are more apparent in raw waters of the U.S. than Canada. This observation may be due to the different methods used to detect and measure coliform populations in drinking water. The U.S. often uses more sensitive tests to detect

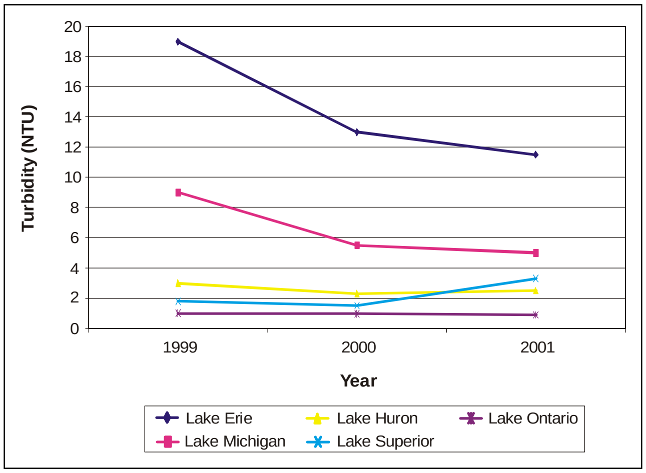

Figure 3. Annual average turbidity for raw water from the Great Lakes Surface.
Source: WTPs across Ontario and the United States

microorganisms, in addition to tests that are common to both countries.

Total coliform by itself is not necessarily harmful, but may indicate the presence of harmful bacteria such as *E. coli*. For any amount of coliform found in Ontario source waters, treatment is necessary. In the U.S., no more than 5% positive coliform samples may be found in distributed waters, and WTPs drawing surface water must provide disinfection treatment. The set standard in both countries for E. coli is zero. A review of SDWIS found only one violation for coliform, from a groundwater WTP, and zero violations for *E. coli*. Ontario does not have a user-friendly way to check for violations, nevertheless, few samples provided by WTPs showed exceedences for either total coliform or *E. coli*. These low exceedence rates, compared to the higher rates of coliform and *E. coli* found in source waters, demonstrate how WTPs within the Great Lakes basin have effective disinfection processes, high water quality in distribution systems, and a low probability of human exposure to either coliform or *E. coli*.

For *Giardia* and *Cryptosporidium*, there is continuing debate regarding their method of detection and the reliability of those results, so there are no proposed numerical guidelines at the moment for Ontario. The U.S. has established treated water standards of 99% physical removal of *Crypto* by filtration, and 99.9% removal and/or inactivation of *Giardia* by filtration and disinfection, ensured by limits on post treatment turbidity and disinfectant residual levels. Accordingly, direct testing by WTPs for these organisms are not mandatory in Ontario or in the U.S. Out of 73 Ontario PWSs, less than 10% provided data for these parameters. In the U.S., less than half of the 41 PWSs provided data. Of the two WTPs from the PWSs that did report data (one using water from a Great Lakes connecting river, and one using water from an inland river), found that samples taken after rain events, regardless of the season, showed higher levels of protozoa present in the water. Of all the WTPs that provided data, non-detection to very low occurrences of the organisms in raw water were generally reported. Accordingly, it was rare to find any *Giardia* or *Crypto* in treated waters (two Great Lakes and one river WTP reported positive samples), and no reports of *Giardia* or *Crypto* were found in the few reported samples from distributed water.

Overall, the quality of drinking water in the Great Lakes is good. This is in large part due to current technologies; few elevated levels that violate drinking water standards and put humans at risk persist past the purification process. The quality of some source waters, however, is still in question. Many contaminants remain at high enough levels to be a concern.

Future Pressures

The greatest pressures come from degraded runoff. Reduced quality of runoff may be caused by a number of reasons, including the increasing rate of industrial development on or near water bodies, low-density urban sprawl, and agriculture, including both crop and livestock operations. In addition, point source pollution, such as that from wastewater treatment plants, also can contribute to pollution. It is unknown to what extent new pressures, such as newly introduced chemicals and invasive species, will impact water quality. If these problems persist, microbiological and chemical contaminants will continue to pose a health risk for humans, as will the disinfection process which creates harmful byproducts.

Future Activities

The importance of high quality source water cannot be over emphasized. In the U.S., states are conducting source water assessments, and the results should start appearing in 2003. Implementation of source water protection measures, including creative ways of mitigating sources of harmful runoff, will continue to be beneficial, and the practice of routine raw water monitoring would also be useful. High quality source water not only reduces the costs associated with treating water, but also promotes a healthier ecosystem and less risk of exposure to harmful contaminants to humans.

Further Work Necessary
The distribution of PWSs currently being examined, and the sources from which they draw water, provide incomplete coverage of treatable drinking water in the Great Lakes basin. Expansion of these data sources would help to provide a more complete and accurate picture of Great Lakes drinking water quality. Better ways of gathering and assessing data are also needed. Since mid-2000, Ontario has been mandating all PWSs to make all drinking water quality reports accessible to the public in a comprehensible and consistent format, similar to the established Consumer Confidence Reports in the U.S. While these are good for identifying violations and exceedences on a periodic basis, a better, standardized way of collecting data would be useful. In addition, the required time it takes to collect data somehow needs to be reduced. A database, accessible to all PWSs, researchers, and the public would help, as would the establishment of a collaborative effort between PWSs and the trend analyzers. Continued evaluation of these ten parameters need to be maintained to insure relevance to human and ecosystem health, as well as feasibility in data collection. The appropriate reporting frequency for this indicator should continue to be every two years, incorporating newly changed regulations and varying pressures.

Acknowledgments
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Contaminants in Snapping Turtle Eggs
SOLEC Indicator #4506 - Indicator Matrix

Assessment: Mixed
Data are not system-wide.

Purpose
Snapping Turtles inhabit and nest in (coastal) wetlands in the Great Lakes basin, particularly the lower Great Lakes. Contaminant trends, and physiological and ecological endpoints, will be assessed in this aquatic-terrestrial reptile. This assessment will provide a better understanding of the impact of contaminants on the physiological and ecological health of the individual turtles and wetland communities.

While other Great Lakes wildlife species may be more sensitive to contaminants than Snapping Turtles, there are few other species that are as long-lived, as common year-round, inhabit such a wide variety of habitats, and yet are limited in their movement between wetlands. Snapping Turtles are also at the top in the aquatic food web and bioaccumulate contaminants. Plasma and egg tissues offer a non-destructive method to monitor recent exposure to chemicals as well as an opportunity for long-term contaminant and health monitoring. Since they inhabit coastal wetlands throughout the lower Great Lakes basin, they allow for multi-site comparisons on a temporal and spatial basis. Consequently, Snapping Turtles are a very useful biological indicator species of local wetland contaminants and the effects of these contaminants on wetland communities throughout the lower Great Lakes basin.

Ecosystem Objective
This indicator supports Annexes 1, 2, 11 and 12 of the GLWQA.

Endpoint
Chemical levels, biological and reproductive measures (exact measures to be confirmed) in Snapping Turtles are not different from those turtles from reference sites away from the Great Lakes, e.g. inland sites from Ontario, Atlantic Canada or the Prairies.

State of the Ecosystem
For more than 20 years, the Canadian Wildlife Service (CWS) has collected Snapping Turtle eggs and examined the species' reproductive success in relation to contaminant levels on a research basis. The following tables provide a summary of contaminant levels in eggs collected at various sites over the past 18 years. Complementary data exist for only one U.S.
Great Lakes coastal wetland, Akwesasne, and these data were collected by CWS.

CWS is currently examining the health of Snapping Turtles in Canadian AOCs on the lower Great Lakes basin (2001–2005), expanding its Snapping Turtle program by adding physiological endpoints (e.g., immune and thyroid functions, oxidative stress) to previously measured endpoints (e.g., contaminant levels in eggs, hatching success and deformity rates).

The earlier program has shown that contaminants in Snapping Turtle eggs change over time and between sites on the Great Lakes basin, with significant differences between contaminated and reference sites continuing to occur (Bishop *et al.*, 1996, 1998). Snapping turtle eggs collected at two Lake Ontario sites (Cootes Paradise and Lynde Creek) had the highest concentrations of polychlorinated dioxins and number of furans (Bishop *et al*. 1996, 1998). Eggs from Cranberry Marsh (Lake Ontario) and two Lake Erie sites (Long Point and Rondeau Provincial Park) had similar levels of PCBs and organochlorines (Bishop *et al*. 1996, 1998). Eggs from Akwesasne (St. Lawrence River) contained the highest level of PCBs (Bishop *et al*. 1998). Levels of PCBs and DDE increased significantly from 1984 to 1990/91 in eggs from Cootes Paradise and Lynde Creek, but levels of dioxins and furans decreased significantly at Cootes Paradise during this time (Struger *et al*. 1993; Bishop *et al*. 1996). Eggs with the highest contaminant levels also showed the poorest developmental success (Bishop *et al.* 1991, 1998). Rates of abnormal development of Snapping Turtle eggs from 1986-1991 were highest at all four Lake Ontario sites compared to other sites studied (Bishop *et al*. 1998).

In 2001, CWS collected Snapping Turtle tissues from three Areas of Concern (AOCs), the St. Clair and Detroit Rivers, and Wheatley Harbour, and two reference sites. The CWS found that clutch size, which refers to the number of eggs laid by a female, was smallest at the St. Clair River AOC (28 eggs) and largest near Wheatley Harbour (42 eggs) (K. Fernie, CWS unpublished data). Despite having the largest clutches, hatching success was very poor, hatchlings were smaller and had more deformities near the Wheatley AOC compared to reference sites. The growth of young turtles from near the Wheatley Harbour AOC was suppressed, and changes in growth were also seen in juveniles from the St. Clair and Detroit River AOCs. 15% of adult male turtles from one AOC showed effects of being exposed to estrogenic-mimicking contaminants, having a protein in their blood that normally only appears in females. Males from the other two AOC sites had shorter penises relative to their body length. A

Lake	Site	1984	1989-1991	1998-1999	2001-2002[1]
Reference site	Algonquin Park	0.187	0.018	0.020	0.016
Lake St. Clair	St. Clair N.W.A.[2]	1.095	-	-	0.074
Detroit River	Turkey Creek	-	-	-	1.134
Erie	Wheatley area	-	-	-	0.491
Erie	Rondeau Provincial Park	1.093	0.617	-	-
Ontario	Cootes Paradise	1.315	3.575	2.956	1.306
Ontario	Lynde Creek	-	1.430	-	-
St. Lawrence River	Akwesasne	0.869	3.946	6.373[3]	-

Figure 1. Total PCB concentrations in Snapping Turtle eggs from selected sites and years. Contaminants are ppm on a wet weight basis.
[1]K. Fernie, unpublished data; [2]St. Clair National Wildlife Area; [3]Mean concentrations for Raquette and St. Regis sites in Akwesasne.
Source: Canadian Wildlife Service contaminants database

Lake	Site	1984	1989-1991	1998-1999	2001-2002[1]
Reference site	Algonquin Park	0.027	0.002	0.002	0.013
Lake St. Clair	St. Clair N.W.A.[2]	0.115	-	-	0.058
Erie	Rondeau Provincial Park	0.040	0.037	-	-
Ontario	Cootes Paradise	0.200	0.389	0.135	0.088
Ontario	Lynde Creek	-	0.232	-	-
St. Lawrence River	Akwesasne	0.010	0.068	0.020 [3]	-

Figure 2. DDE concentrations in snapping turtle eggs from selected sites and years. Concentrations are ppm on a wet weight basis.
[1]K. Fernie, unpublished data; [2]St. Clair National Wildlife Area; [3]Mean concentrations for Raquette and St. Regis sites in Akwesasne.
Source: Canadian Wildlife Service contaminants database

similar finding was also found in alligators inhabiting contaminated sites in Florida.

Future Pressures
Future pressures for this indicator include all sources of contaminants which reach the Great Lakes wetlands, including traditional chemicals (e.g. PCBs, DDT/E, mirex) newly emerging ones (e.g. PAHs, polybrominated diphenyl ethers or flame retardants). Snapping Turtle populations face additional pressures from commercial harvesting of adult turtles and road-side killings during the nesting season in June.

Future Activities
CWS is evaluating the establishment of a long-term monitoring program involving the Snapping Turtle and is using the current study (2001-2005) to assess appropriate methodologies. Such a program would likely involve the following periodic measurements:

1. total DDT, PCBs/PCDFs/PCDDs and other organochlorines, mercury and other metals in plasma and eggs from multiple Great Lakes sites.
2. various biological endpoints: clutch size, hatching success, vitamin A, thyroid function, liver enzyme induction, and clinical chemistry analyses of adult turtles.

Further Work Necessary
The health and contaminant status of Snapping Turtles should be monitored on a regular basis across the Great Lakes basin where appropriate. Once the usefulness of the indicator is confirmed, it will be necessary to foster a complementary U.S. program to interpret basin-wide trends. This species offers an excellent opportunity to monitor the health and contaminant concentrations in coastal wetland populations. Immune function, oxidative stress relating to neuro-degenerative problems (e.g., cancer, immune disorders), and newly emerging contaminants also need to be examined in the long-term monitoring program.

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Effect of Water Level Fluctuations

SOLEC Indicator #4861

Assessment: Mixed

Data are available for water level fluctuations for all lakes. A comparison of wetland vegetation along regulated Lake Ontario to vegetation along unregulated Lakes Michigan and Huron provides insight into the impacts of water level regulation.

Purpose

The purpose of this indicator is to examine the historic water levels in all the Great Lakes, and compare these levels and their effects on wetlands with post-regulated levels in Lakes Superior and Ontario, where water levels have been regulated since about 1914 and 1959, respectively. Naturally fluctuating water levels are known to be essential for maintaining the ecological health of Great Lakes shoreline ecosystems, especially coastal wetlands. Thus, comparing the hydrology of the Lakes serves as an indicator of degradation caused by the artificial alteration of the naturally fluctuating hydrological cycle. Furthermore, water level fluctuations can be used to examine effects on wetland vegetation communities over time as well as aid in interpreting estimates of coastal wetland area, especially in those Great Lakes for which water levels are not regulated.

Ecosystem Objective

The ecosystem objective is to maintain the diverse array of Great Lakes coastal wetlands by allowing, as closely as is possible, the natural seasonal and long-term fluctuations of Great Lakes water levels. Great Lakes shoreline ecosystems are dependent upon natural disturbance processes, such as water level fluctuations, if they are to function as dynamic systems. Naturally fluctuating water levels create ever-changing conditions along the Great Lakes shoreline, and the biological communities that populate these coastal wetlands have responded to these dynamic changes with rich and diverse assemblages of species.

State of the Ecosystem

Water levels in the Great Lakes have been measured since 1860, but 140 years is a relatively short period of time when assessing the hydrological history of the Lakes. Sediment investigations conducted by Thompson and Baedke on the Lake Michigan-Huron system indicate quasi-periodic lake level fluctuations (Fig. 1), both in period and amplitude, on an average of about 160 years, but ranging from 120-200 years. Within this 160-year period, there also appear to be sub-fluctuations of approximately 33 years. Therefore, to assess water level fluctuations, it is necessary to look at long-term data.

Because Lake Superior is at the upper end of the watershed, the fluctuations have less amplitude than the other Lakes. Lake Ontario (Fig. 2), at the lower end of the watershed, more clearly shows these quasi-periodic fluctuations and the almost complete elimination of the high and low levels since the Lake level began to be regulated in 1959, and more rigorously since 1976. For example, the 1986 high level that was observed in the other Lakes was eliminated from Lake Ontario. The level in Lake Ontario after 1959 contrasts with that of Lake Michigan-Huron (Fig. 3), which shows the more characteristic high and low water levels.

The significance of seasonal and long-term water level fluctuations on coastal wetlands is perhaps best explained in terms of the vegetation, which, in addition to its own diverse composition, provides the substrate, food, cover, and habitat for many other species dependent on coastal wetlands.

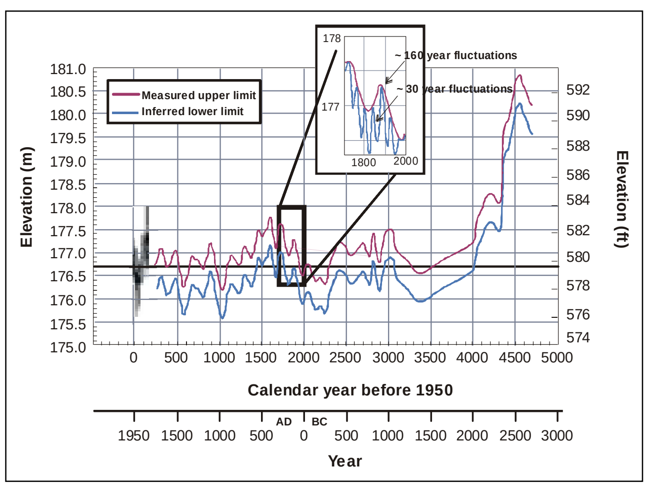

Figure 1. Sediment investigations on the Lake Michigan-Huron system indicates quasi-periodic lake level fluctuations.

Source: National Oceanic and Atmospheric Administration, 1992 (and updates)

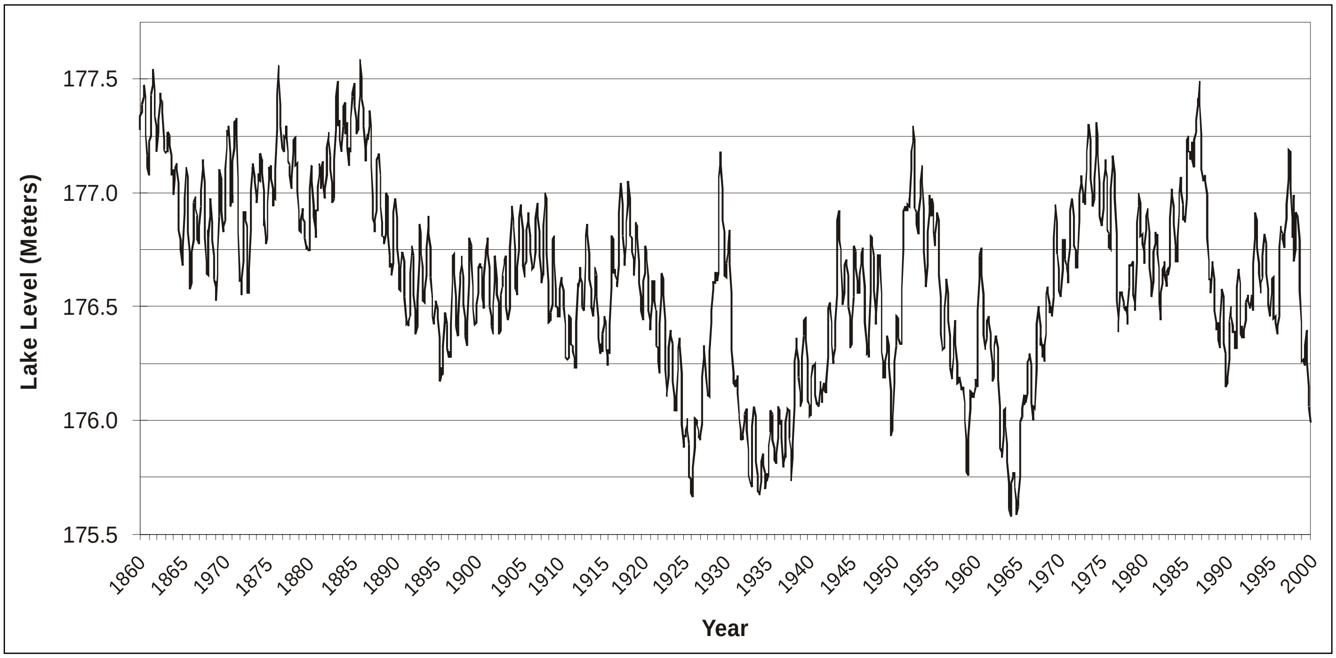

Figure 2. Actual water levels for Lakes Huron and Michigan. IGLD-International Great Lakes Datum. Zero for IGLD is Rimouski, Quebec, at the mouth of the St. Lawrence River. Water level elevations in the Great Lakes/St. Lawrence River system are measured above water level at this site.
Source: National Oceanic and Atmospheric Administration

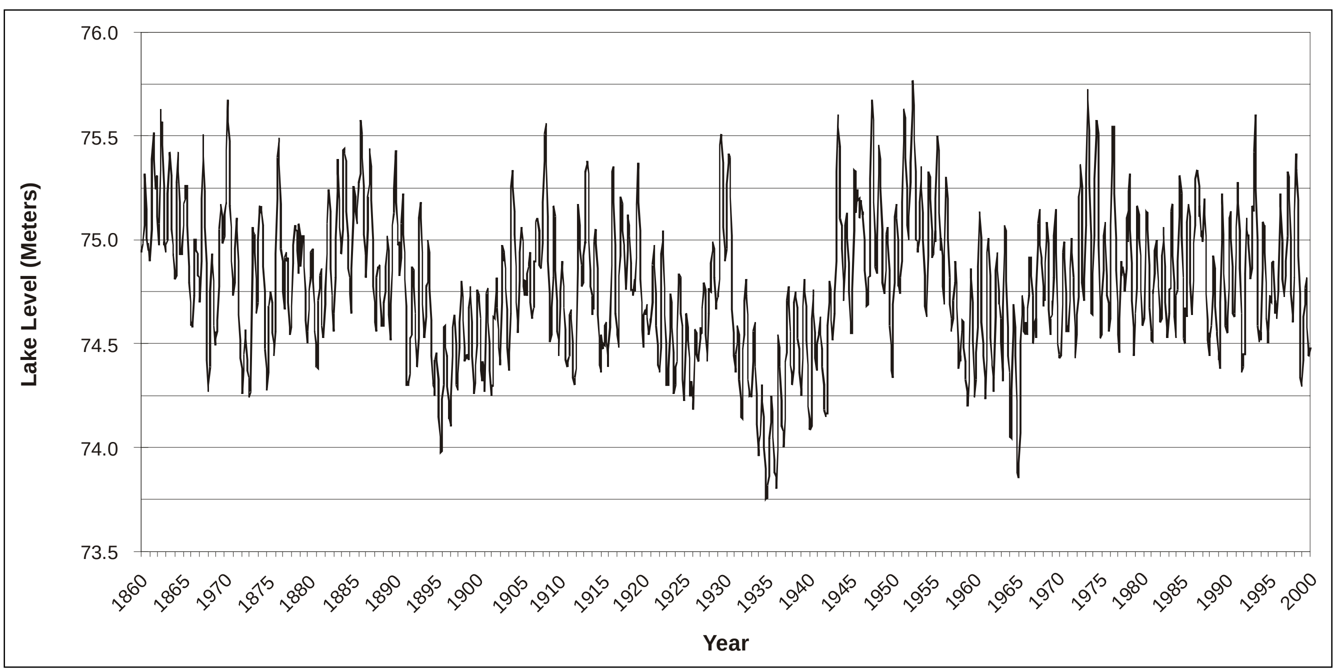

Figure 3. Actual water levels for Lake Ontario. IGLD-International Great Lakes Datum. Zero for IGLD is Rimouski, Quebec, at the mouth of the St. Lawrence River. Water level elevations in the Great Lakes/St. Lawrence River system are measured above water level at this site.
Source: National Oceanic and Atmospheric Administration

Seasonal water level fluctuations result in higher summer water levels and lower winter levels. Additionally, the often unstable summer water levels ensure a varied hydrology for the diverse plant species inhabiting coastal wetlands. Without the seasonal variation, the wetland zone would be much narrower and less diverse. Even very short-term fluctuations resulting from changes in wind direction and barometric pressure can substantially alter the area inundated, and thus, the coastal wetland community.

Long-term water level fluctuations, of course, have an impact over a longer period of time. During periods of high water, there is a die-off of shrubs, cattails, and other woody or emergent species that cannot tolerate long periods of increased depth of inundation. At the same time, there is an expansion of aquatic communities, notably submergents, into the newly inundated area. As the water levels recede, seeds buried in the sediments germinate and vegetate this newly exposed zone, while the aquatic communities recede outward back into the Lake. During periods of low water, woody plants and emergents expand again to reclaim their former area as aquatic communities establish themselves further outward into the Lake.

The long-term high-low fluctuation puts natural stress on coastal wetlands, but is vital in maintaining wetland diversity. It is the mid-zone of coastal wetlands that harbors the greatest biodiversity. Under more stable water levels, coastal wetlands occupy narrower zones along the Lakes and are considerably less diverse, as the more dominant species, such as cattails, take over to the detriment of those less able to compete under a stable water regime. This is characteristic of many of the coastal wetlands of Lake Ontario, where water levels are regulated.

Future Pressures

Future pressures on the ecosystem include additional withdrawals or diversions of water from the Lakes, or additional regulation of the high and low water levels. These potential future pressures will require direct human intervention to implement, and thus, with proper consideration of the impacts, can be prevented. The more insidious impact could be caused by global climate change. The quasi-periodic fluctuations of water levels are the result of climatic effects, and global warming has the potential to greatly alter the water levels in the Lakes.

Future Actions

The Lake Ontario-St. Lawrence River Study Board is undertaking a comprehensive 5-year study for the International Joint Commission (IJC) to assess the current criteria used for regulating water levels on Lake Ontario and in the St. Lawrence River.

The overall goals of Environment/Wetlands Working Group (of the IJC study) are (1) to ensure that all types of native habitats (floodplain, forested and shrubby swamps, wet meadows, shallow and deep marshes, submerged vegetation, mud flats, open water, and fast flowing water) and shoreline features (barrier beaches, sand bars/dunes, gravel/cobble shores, and islands) are represented in an abundance that allows for the maintenance of ecosystem resilience and integrity over all seasons, and (2) maintain hydraulic and spatial connectivity of habitats to ensure that fauna have access, temporally and spatially, to a sufficient surface of all the types of habitats they need to complete their life cycles.

The environment/wetlands component of the IJC study provides a major opportunity to improve the understanding of past water-regulation impacts on coastal wetlands. The new knowledge will be used to develop and recommend water level regulation criteria with the specific objective of maintaining coastal wetland diversity and health.

Also, continued monitoring of water levels in all of the Great Lakes is vital to understanding coastal wetland dynamics and the ability to assess wetland health on a large scale. Fluctuations in water levels are the driving force behind coastal wetland biodiversity and overall wetland health. Their effects on wetland ecosystems must be recognized and monitored throughout the Great Lakes basin in both regulated and unregulated Lakes.

Further Work Necessary

Human-induced global climate change could be a major cause of lowered water levels in the Lakes in future years. Further study is needed on the impacts of water level fluctuations on other nearshore terrestrial communities.

Also, an educated public is critical to ensuring wise decisions about the stewardship of the Great Lakes basin ecosystem, and better platforms to getting understandable information to the public are needed.

Acknowledgments
Author: Duane Heaton, USEPA-Great Lakes National Programs Office, Chicago, IL.
Much of the information and discussion presented in this summary is based on work conducted by the following: Douglas A. Wilcox, Ph.D. (US Geological Survey / Biological Resources Division); Todd A. Thompson, Ph.D. (Indiana Geological Survey); Steve J. Baedke, Ph.D. (James Madison University)

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Mass Transportation

SOLEC Indicator #7012 - Indicator Matrix

Assessment: Mixed
Data from multiple sources are not consistent.

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

Ecosystem Objective
This indicator supports one of the general objectives from the Great Lakes Water Quality Agreement "These waters should be free from materials...directly and indirectly entering the water as a result of human activity that...will produce conditions that are toxic or harmful to...life", as well as Annex 15 of the Agreement. In addition, this indicator promotes sustainable development as interpreted by Canada and the United States through continuing efforts of agencies, such as the Canadian National Roundtable on Environment and Economy.

State of the Ecosystem
For this indicator, public transit ridership data for the years 1993 – 2000 were collected from 38 transit authorities in Ontario, and data for the years 1996 – 2000 were collected from 15 transit agencies in the United States within the Great Lakes basin. This report encompasses a more extensive geographical area than the 2000 SOLEC report that cited only four communities that were specifically along Lake Ontario and Lake Erie. The U.S. data are based on the daily average number of unlinked trips (where transfers are counted as a different trip), of which approximately 90% are bus or rail trips. The other approximately 10% are based on less used forms of public transportation, such as van/car pooling. Canadian data are based on adult ridership numbers for each transit system cited, not differentiating between linked or unlinked trips, except for the regional transit authority or GO Transit system.

For this SOLEC, although municipal populations in all Canadian cities cited for this indicator remain relatively constant, the trend is an increase in public transit ridership in many established urban areas particularly in Southern Ontario, and the converse for rural areas in Northern Ontario. The increase in public transit ridership from 1993-2000 is evident in the established urban areas of the cities of Toronto and Hamilton, and in developing suburban areas of Markham, Oshawa and Richmond Hill, all constituting the Greater Toronto Area (GTA) and Brampton, Mississauga and Oakville, bordering the GTA. More importantly, is a visible increase in ridership for transit agencies serving inter-regional areas, or agencies linking other agencies, specifically the GO Transit in Ontario, servicing numerous areas within the GTA, including the developing suburban communities. (Fig. 1)

The observed increase in Canadian public transit ridership trend particularly for transit agencies working with other transit agencies, support the conclusions of the previous SOLEC showing a direct relationship between public transportation and the degree of urban density. Toronto, as the most populous, and most established community of the Canadian cities cited for this study, showed the highest public transit ridership, (Fig. 2), and the development of urban centers bordering the GTA, such as Mississauga, Brampton and Oakville, increases the use of public transportation, as well. Public transit ridership numbers in U.S. cities and surrounding suburbs remained relatively constant from 1996 to 2000 (Fig. 3). The majority of transit agencies have not seen more than a two percent change in ridership numbers, and less than 10% of the service area population use public transportation. The four agencies that showed the four highest transit use percentages are located in the four largest cities. Of these four, the Chicago Transit Authority (CTA), which serves the city of Chicago and 38 suburbs, had the largest percent of transit use. Chicago is the largest city in the Great Lakes basin and its transit use numbers are climbing.

These trends show how transit system accessibility to densely populated areas determine the percentage of transit use rather than the size of a city. Milwaukee is half the size of the city of Detroit, yet more people are using the public transit system. Detroit's population may be more spread out or Milwaukee's population may be more concentrated within the city limits. The Northeast Illinois Regional Commuter Railroad

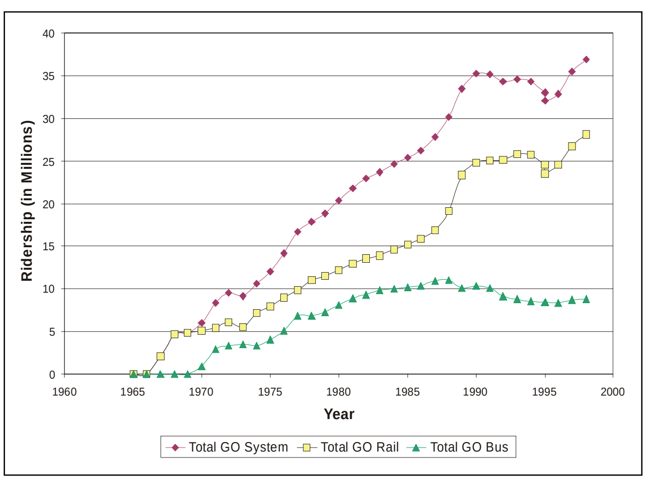

Figure 1. GO Transit System's ridership trends, 1965-1998, including total two-way rides, weekday plus weekend, trips without passengers transferring from a bus-train or train-bus connection. Data are only from 1965-1998 because the reporting system for trips without transfers h as been abandoned by the transit system.
Source: GO Transit System, Toronto, Ontario

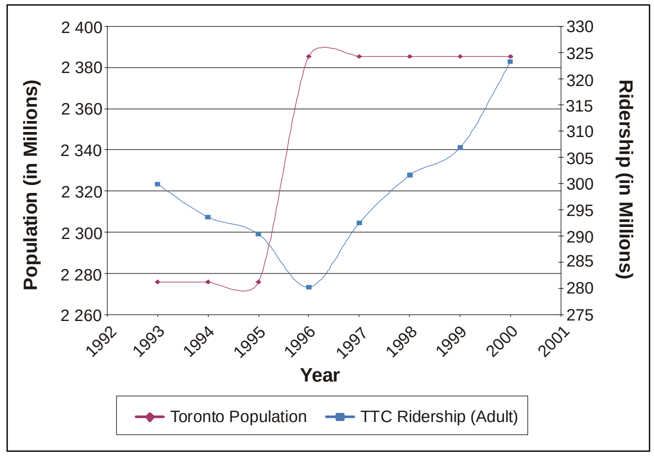

Figure 2. Toronto Transit Commission's annual ridership trend from 1993-2000.
Source: Toronto Transit Commission (TTC)

Corporation (NIRCRC) has a smaller percentage of transit use than Chicago's other reported transit agency, the CTA. NIRCRC's service area is twice as large as the CTA's, even reaching into surrounding states, while the CTA focuses more on inner city travel. Percentage of transit use is high where the concentration of people is the highest.

Future Pressures

The increasing rate of industrial development and land use segregation in suburban areas present the most pressure for this indicator and for the Great Lakes ecosystem. This low-density urban sprawl is more suitable for private motor vehicle commute, and the high availability of space allows for extensive parking lots. Public transportation for traveling to and from work is more efficient and less polluting than traveling via private automobile, in terms of time saved from traffic and resource utilization. However, the convenience afforded by a private motor vehicle for traveling to and from work seems to outweigh the benefits of public transit use, depending on how well linkages are established between and within transit systems. Also, if some cities continue to have low ridership numbers, then there will be empty or near-empty buses still running that may be more polluting than the equivalent number of private motor vehicles.

Future Action

Increased communication and assistance between different levels of government, public interest groups,

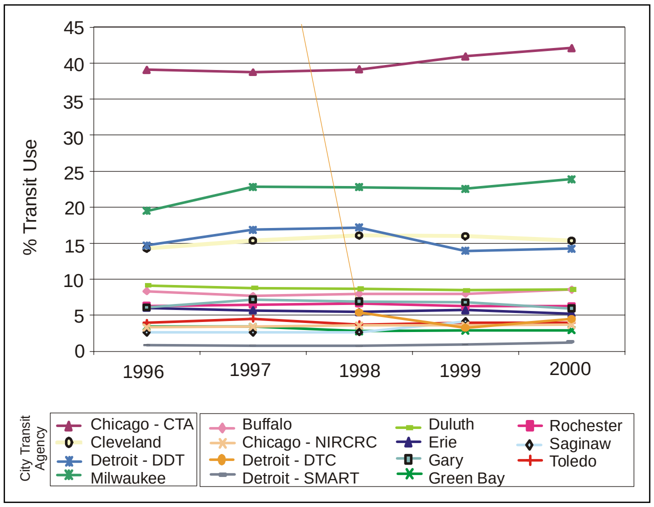

Figure 3. Percentage of transit use for 15 U.S. Transit Agencies in the Great Lakes basin from 1996-2000. The dramatic decrease in Detroit-DTC's % of transit use in 1998 is due to a service area increase of approximately 15.5 times the area reported in 1997. SMART = Suburban Mobility authority for Regional Transit, CTA = Chicago Transit Authority, NIRCRC = Northeast Illinois Regional Commuter Railroad Corporation, DDT = Detroit Department of Transportation, DTC = Detroit Transportation Corporation.
Source: National Transit Database

academia and transit authorities are necessary for promoting public transit use, as well as the development of cost-effective public transit infrastructure for more efficient transit routes and transit fares. Both of these will mitigate the pressures on mass transportation and the ecosystem. Toronto is a prime example as the city is currently working with the federal and provincial governments to improve the Toronto Transit Commission's infrastructure to improve its service to the public. Ultimately this will relieve the stress to the Great Lakes ecosystem caused by pollution from private motor vehicle use.

Further Work Necessary

Development of an efficient and consistent database accessible to all transit authorities, researchers and the public in the entire Great Lakes basin would help in assessing the trends of public transit use in a larger context, increasing access to data and consistency in the data for improved efficiency of reporting for the indicator. A census in each transit agency's service area may be a better way to determine percent ridership since statistics for this report are based on "unlinked trips", or the number of people that board public transportation vehicles. One person could be counted multiple times depending on the number of trips or transfers taken, whereas a census would count the number of people, not the number of trips, and may provide more insight into why people choose to or choose not to use public transportation. The appropriate reporting frequency for this indicator is approximately 6 years as it takes time to collect consistent and comparable data from each transit authority. From the data collected for this study, trends are clearer with collected data spanning the suggested reporting frequency time frame.

Acknowledgments

This report was prepared by Angelica Guillarte, Environment Canada and Mary Beth Giancarlo, USEPA – Great Lakes National Program Office.

Thanks to Michael Canzi of the Canadian Urban Transit Association and transit authorities for submitting the requested data. The Canadian Urban Transit Association (CUTA) is an association of providers of urban transit services, suppliers and related organization in Canada.

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All Canadian Transit Authorities who submitted requested data:

Ajax/Pickering Transit
110 Westney Road South
Ajax, Ontario L1S 2C8

Barrie Transit
24 Maple Avenue, Unit 205
Barrie, Ontario L4M 7W4

GO Transit
20 Bay St., Suite 600
Toronto, ON M5W 2W3

Guelph Transit
59 Carden Street
Guelph, ON N1H 3A1

Hamilton Street Railway Company
City of Hamilton: Transportation, Operations and Environment-Transit
Mount Hope, ON L0R 1W0

Mississauga Transit
975 Central Parkway West
Mississauga, ON L5C 3B1
Niagara Transit Commission
4320 Bridge Street
Niagara Falls, Ontario L2E 2R7

Oakville Transit
Town of Oakville,
480 Wyecroft Road, P.O. Box 310
Oakville, ON L6J 5A6

Oshawa Transit Commission
710 Raleigh Avenue
Oshawa, ON L1H 3T2

St. Catharines Transit
2012 First Street South RR3
St. Catharines, Ontario L2S 3V9

Stratford Transit
City of Stratford, Communities Services Department
Transit Division, 27
Stratford, ON N5A 6W3

Toronto Transit Commission
1900 Yonge Street
Toronto, ON M4S 1Z2

Whitby Transit
575 Rossland Road East
Whitby, Ontario L1N 2M8

Water Use

SOLEC Indicator #7056 - Indicator Matrix

Assessment: Mixed

Data from multiple sources are not consistent.

Purpose

This indicator measures the per capita water use in the Great Lakes basin and indirectly measures the demand for water resources within the basin and the amount of wastewater generated.

Ecosystem Objective

This indicator provides a quantitative measure of the rate at which natural resources are being used. Current North American water use rates are in excess of 300 liters per day; making Canada and the U.S. among the highest water using nations, *per capita*, on the Earth. This high consumptive rate of water use results in increased demand to pump and treat water in addition to considerable wastewater pollution.

Sustainable development is a societal goal for the Great Lakes basin. Resource conservation needs to be a top priority in order to reduce the amount of water that is used and the amount of wastewater that results from such water use.

This indicator supports Annex 8 of the Great Lakes Water Quality Agreement.

State of the Ecosystem

Hydroelectric water use continues to be the largest use of all the categories at approximately 95% for each reported year. Almost all of the water withdrawn from the St. Lawrence River basin is for hydroelectric power, which heavily influences the total water use for the basin (Figure 1). However, hydroelectric water use is considered to be an "instream" use, meaning that the water is not actually removed from the source, and therefore does not add to consumptive use.

From a sectoral analysis of municipal water use on the Canadian side of the Great Lakes basin, residential water use accounts for almost 50% of the total municipal water use in 1999 (Figure 2). The residential sector displays an increase in municipal water use by 58.7% from 1983-1999, in the commercial sector there is an increase in municipal water use of 54.8% from 1983-1999. In addition, there is an increase in industrial municipal water use by 42.4% over the same period. The only sector which displays a decrease in municipal water was the "other" category-the term for the daily average flow that is not accounted for (i.e. system leaks). From 1983-1999 this sector decreased by 10.8%. The rise in residential water use can be attributed to an increase in municipal populations, an increase in economic activity and in addition, recent warmer summer temperatures, resulting in increased amounts of water being used for lawn maintenance (National Indicators Office, 2001).

When analyzing the trends in municipal water use in Canadian municipalities of populations greater than 1000 in the Great Lakes basin, the average *per capita* water use over *all* sectors and municipalities has actually decreased by 15% from 1983-1999 (Figure 3). This decrease in per capita water use could be attributed to new technological advances in water saving devices, metering and full-cost volume-based, user pay systems which provide economic incentives to promote water conserving behavior (National Indicators Office, 2001). Per capita water use in the United States has increased by approximately ten percent from 1985 to 1995 (Figure 3) even though the population served decreased in 1995. This increase in per capita water use could be attributed to an increase in public use and losses, and possible water transfer between states or regions.

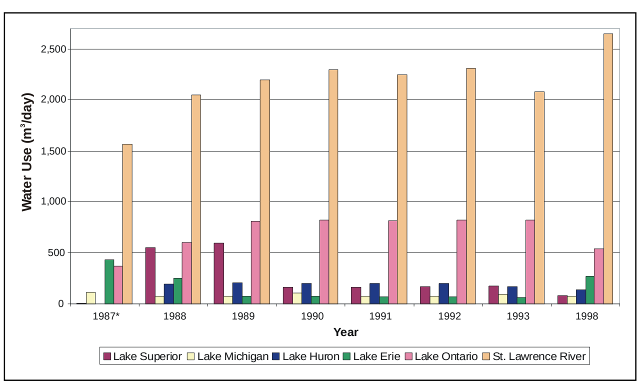

Figure 1a. Great Lakes water, other surface water , and groundwater use by basin from 1987 to 1993, and 1998. The Province of Ontario did not submit water use data for 1987.

Source: Great Lakes Commission, Annual Report of the Great Lakes Regional Water Use database repository. Adapted for SOLEC by U.S. EPA-GLNPO

Apart from hydroelectric generation, thermoelectric generation (fossil fuel and nuclear) makes up over 50% of the total water (surface and groundwater) used in the U.S. side of the Great Lakes basin. Industrial and public water supply make up approximately 40% of the water use, and less than 10% of the water used is from self-supplied domestic, irrigation, livestock, and other categories. These percentages have remained relatively stable since 1987. New York State (NYS) by far uses the most

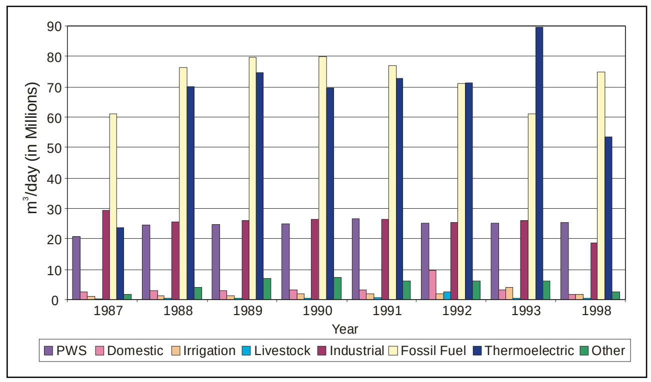

Figure 1b. Great Lakes water, other surface water, and groundwater use by category in the Great Lakes basin from 1987 to 1993, and 1998 (without Hydroelectricity). The Province of Ontario did not submit water use data for 1987. PWS = Public Water Supply.

Source: Great Lakes Commission, Annual Report of the Great Lakes Regional Water Use database repository. Adapted for SOLEC by U.S. Environmental Protection Agency-Great Lakes National Program Office

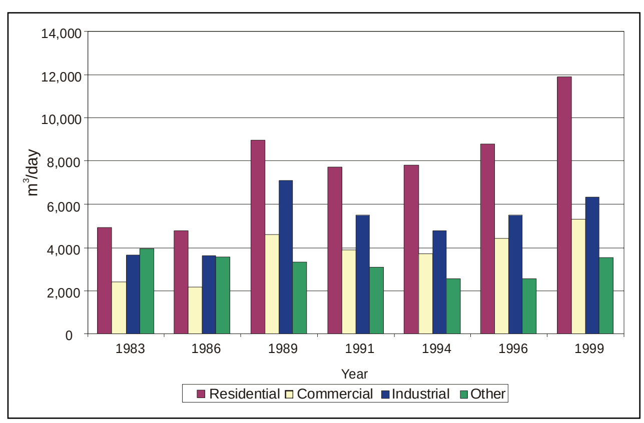

Figure2. Daily average municipal water use by sector on the Canadian side of the Great Lakes basin, 1983-1999.

Source: Municipal Water Use Database (MUD). Adapted for SOLEC by Environment Canada

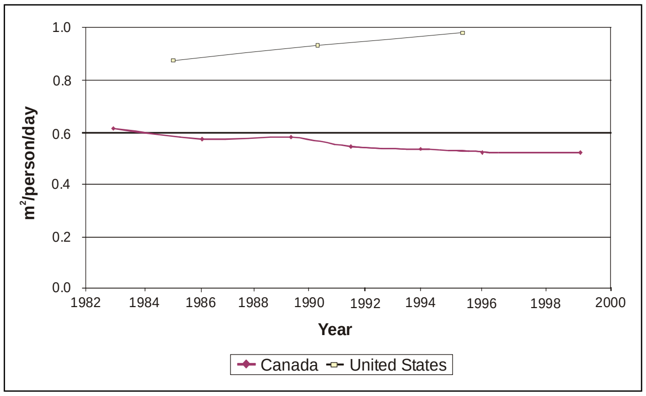

Figure 3. Average municipal per capita water use on the Canadian, 1983-1999, and U.S., 1985-1995, sides of the Great Lakes basin.
Source: Municipal Water Use Database (MUD). Adapted for SOLEC by Environment Canada, and the U.S. EPA-GLNPO

water, which is the result of a large hydroelectric water use. For example, in 1998, hydroelectric made up 98% of the total water use for NYS. There is no consistent trend for water withdrawls among the Great Lakes states (Figure 4). For example, in 1998 Illinois's water use was reduced by almost 50% due to the shutting down of a nuclear power plant. Michigan had been unable to submit current water use data in the Great Lakes Commission format until 1998. The data from 1987 to 1993 has been based on Michigan's base year data of 1985. Water use data from Minnesota for 1988 and 1989 has been removed since it was reported erroneously.

Future Pressures
As population and economic activity are predicted to increase in the Great Lakes basin, it is expected that an increased demand for water will also continue. Water use in the Great Lakes will continue to increase especially for thermoelectric power, agriculture, and residential uses. The combined projections of both the U.S. and Canada indicate a modest increase in water use of ~5% for the entire Great Lakes basin between 1995-1996, and 2020-2021 (Michigan DEQ, 2000) and based on Canadian data displayed in Figure 2, this proposed modest increase in residential water use has already been surpassed. In order to mitigate the effects of a growing consumptive population and possible decline in lake levels due to climate change, water use conservation programs need to be implemented in order to achieve rates similar to those in European cities.

Currently there is no net loss of water due to diversions, however, growing communities in the U.S. near the basin border, where water is scarce and of poor quality, may look to the Great Lakes as a source in the future.

Future Activities
There is a need in the Great Lakes basin for municipalities to implement water conservation strategies in order to reduce excessive water use in the basin. According to Great Lakes United, in 1997 some municipalities in the basin, including Chicago, Toronto and Hamilton did not meter all water usage. The installation of water meters can reduce water usage by 15-20%. The pricing of water in the Great Lakes basin is also extremely cheap. According to Great Lakes United (1997), households in Canada and the U.S. use twice as much water as their European counterparts, however they only pay half as much for it. Thus, there is a direct correlation between the price of water and the amount used. Low water pricing encourages high water consumption and, high pricing seems to encourage conservation.

Further Work Necessary
From sectoral analysis in 1999, residential water use in the Ontario portion of the Great Lakes basin accounted for almost half of the total municipal water used. This finding indicates a need for a better

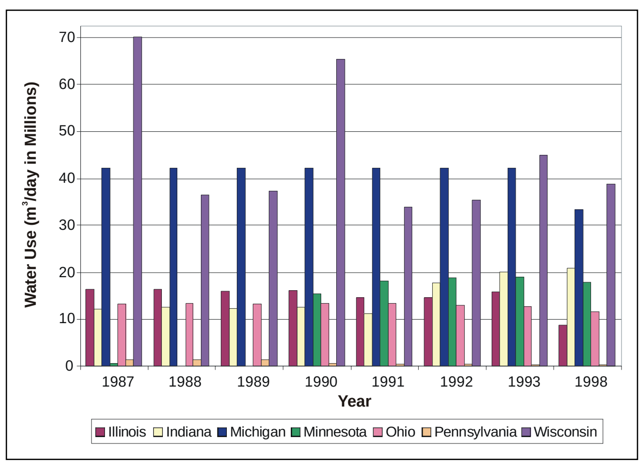

Figure 4. Water use by jurisdiction in the U.S. side of the Great Lakes Basin from 1987 to 1993, and 1998 (without New York State).
Source: Great Lakes Commission, Annual Report on the Great Lakes Regional Water Use Data Base Repository, adapted for SOLEC by U.S. EPA-GLNPO

understanding of the relationship between population growth, economic growth and water use.

In addition there needs to be a concerted effort, and available resources, for consistently collecting and reporting on data on both sides of the border. Great Lakes Commission's water use data are based on water license permits, whereas Environment Canada's data are based on surveys of actual water use from major users in the basin, and therefore tend to be lower. Another agency, the United States Geological Survey, collects water use data by county, then aggregates them by state, makes estimates of missing data elements, and estimates actual water use for its five year reports.

Acknowledgments
Authors: Melissa Greenwood, Environment Canada, Downsview, ON and Mary Beth Giancarlo, U.S. EPA-GLNPO, Chicago IL. Marilyn Ratliff (Great Lakes Commission) and Deborah Lumia and Howard Perlman (USGS) assisted in the preparation of this report.

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Note: All Canadian data collected were for Municipalities in Ontario with a population greater than 1000, and included all surface water and municipal groundwater wells. All United States data (and provincial data from the Great Lakes Commission) includes all surface water and all groundwater wells.

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Energy Consumption
SOLEC Indicator # 7057 - Indicator Matrix

Assessment: Mixed Deteriorating (U.S. section of Lake Superior only)
Data are not system-wide.

Purpose
To assess the amount of energy consumed in the Great Lakes basin per capita, and to infer the demand for resource use, the creation of waste and pollution, and stress on the ecosystem.

Ecosystem Objective
Sustainable development is a generally accepted goal in the Great Lakes basin. This indicator supports Annex 15 of the Great Lakes Water Quality Agreement. Resource conservation minimizing the unnecessary use of resources is an endpoint for ecosystem integrity and sustainable development

State of the Ecosystem
Data extracted from the Energy Information Administration (EIA) 1998 "Retail Electricity Sales" tables for the 29 utilities operating in the Lake Superior basin can be used to calculate the following

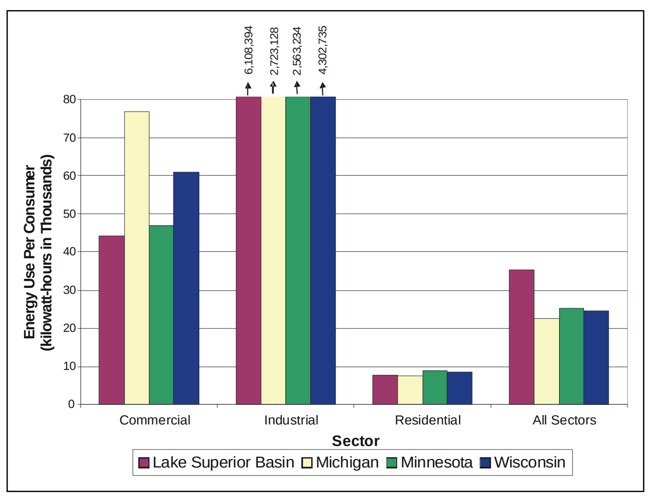

Figure 1. Electric energy use per consumer by sector in the U.S. Lake Superior basin and in the states of Michigan, Minnesota, and Wisconsin in 1998. Note that this is not energy use per capita. Data are from Energy Information Administration.
Source: GEM Center for Science and Environmental Outreach, Michigan Technological University

averages of energy use: 7,749 kilowatt-hours (kWh) per residential consumer, 6,108,394 kWh per industrial consumer, 44,116 kWh per commercial consumer, and 35,337 kWh per consumer for all sectors (Figure 1). Note that consumers may include households and businesses and is not equivalent to per capita energy use. Overall energy use per consumer is higher for the Lake Superior basin than for Michigan, Minnesota, or Wisconsin, mainly because industrial energy use is much higher. Commercial energy use per consumer is lower in the basin than in any of the three states, as is residential energy use, except for Michigan, which is slightly less than for the basin.

Total electric energy use (reported in Megawatt-hours) could also be used as a measure independent of the number of consumers (Figure 2).

Future Pressures

The Energy Information Administration gathers data on total energy consumption by sector and state over time. Michigan, as the only state that is almost entirely in the Great Lakes basin, can be used as an example of electricity consumption trends over time (Figure 3). Electric energy consumption in Michigan rose 21.8 percent between 1988 and 1998, mainly due to increases in the commercial and residential sectors since 1992.

Canada's Energy Outlook 1996-2020 (http://nrn1.nrcan.gc.ca:80/es/ceo/toc-96E.html) notes that "a significant amount of excess generating capacity exists in all regions of Canada" because demand has not reached the level predicted when new power plants were built in the 1970s and 1980s. Demand is projected to grow at an average annual rate of 1.3 percent in Ontario and 1.0 percent in Canada overall between 1995 and 2020, compared to 2.6 percent annually from 1980 to 1995. From 2010-2020, Ontario will add 3,650 megawatts of new gas-fired and 3,300 megawatts of clean coal-fired capacity. Several hydroelectric plants will be redeveloped, but none appear to be in the Lake Superior basin. Renewable resources are projected to quadruple between 1995 and 2020, but will contribute only 3 percent of total power generation.

Future Activities

A report by the nonprofit Union of Concerned Scientists (UCS), *Powerful Solutions for Wisconsin: Seven Ways to Switch to Renewable Electricity*, cites Wisconsin's proactive policies, such as a Climate Change Action Plan, that encourage investment in energy efficiency and renewable energy (www.ucsusa.org):

> A UCS analysis for Wisconsin found that an 800 MW mix of new renewables would create about 22,000 more job-years than new gas and coal plants over a 30-year period. A study by the Wisconsin Energy Bureau found renewables would produce over three times more jobs, income and economic activity than the same amount of electricity generated from new coal and natural gas power plants. They also found that a 75 percent increase in renewable energy use by 2010 (equal to 775 MW of new renewables) would generate approximately 3,316 more jobs, $81 million in higher disposable income and a $165 million increase in gross state product than conventional power plant investments. This scenario also would reduce 20 percent of the growth in electricity sector CO2 emissions between 1990 and 2010 and save an estimated $60 million per year in potential future environmental regulations on carbon emissions.

As of 1998, renewables, mainly hydropower, supplied less than three percent of Wisconsin's

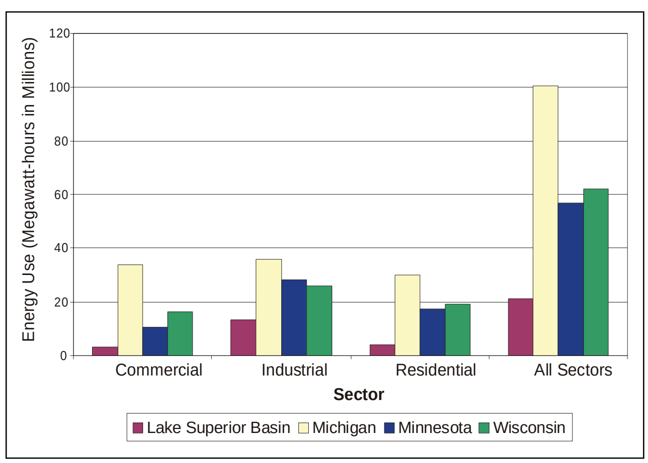

Figure 2. Total electric energy use (MWh) in the U.S. Lake Superior basin by sector, 1998. Data are from Energy Information Administration.
Source: GEM Center for Science and Environmental Outreach, Michigan Technological University

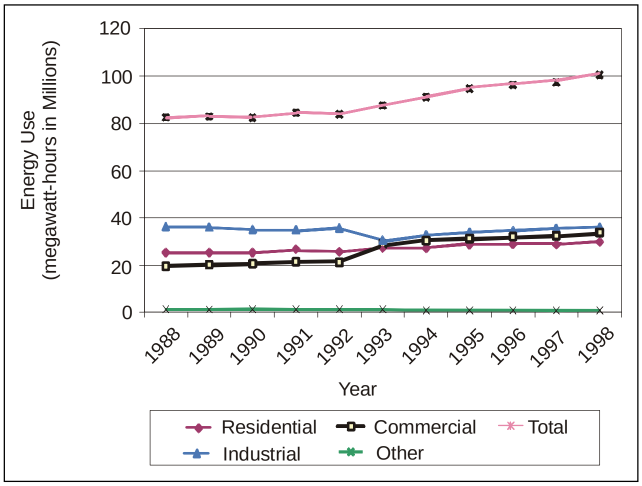

Figure 3. Electric energy consumption in Michigan by sector, 1988-1998. Data are from Energy Information Administration.
Source: GEM Center for Science and Environmental Outreach, Michigan Technological University

electricity. A 1993 UCS report, *Powering the Midwest*, identified biomass (crops of switchgrass and hybrid poplars) as a potential source of 30 percent of Wisconsin's energy needs at 5 cents per kilowatt-hour and 60 percent for an extra penny of production costs. Wind power could provide almost half the state's total demand at 6 cents per kilowatt-hour and is particularly suited to areas near Lake Superior. Solar energy may help reduce peak loads during hot weather. Wisconsin has developed a statewide daylighting design services program to educate architects, builders, and engineers on incorporating daylighting into Wisconsin building practices.

The nonprofit RENEW Wisconsin is working with utilities to seek national third-party certification for their renewable power products, to which about 70 percent of Wisconsin energy customers currently have access (http://renewwisconsin.org/greenpow.html). For example, RENEW negotiated an agreement with Wisconsin Electric Power to supply its Energy for Tomorrow program with renewable energy generated primarily in Wisconsin, with public support and marketing assistance from RENEW and Wisconsin's Environmental Decade.

Another UCS report, *Assessing Wind Resources in Minnesota: A Guide for Landowners, Project Developers and Power Suppliers*, provides guidance in assessing potential wind resources. The report includes a map of annual average wind power in the U.S. that shows moderate wind power classes along Lake Superior.

Further Work Necessary

Electric power data for the entire United States is available on the Internet from the Energy Information Agency (EIA) of the U.S. Department of Energy (http://www.eia.doe.gov/fuelelectric.html). Databases include power generation by utility company, peak demand output of individual plants, and energy use per consumer by utility and by residential, industrial, and commercial sectors. According to EIA state electricity profiles, utility and non-utility generation per person is 10,240 kWh (rank 36) in Michigan, 10,030 kWh (rank 37) in Minnesota, and 10,790 kWh in Wisconsin (rank 34) (http://www.eia.doe.gov/cneaf/electricity/st_profiles/toc.html). Electric energy consumption per consumer is reported by utility service area, essentially making it impossible to match to any census population figures for the Lake Superior basin. The "per consumer" approach for residential consumption, however, should be a reasonable measure of household consumption over time. The commercial and especially industrial sectors may be more variable if major consumers leave or join the grid. Deregulation may also complicate the tracking of energy produced in one region but consumed in another. Per capita electric energy consumption, the

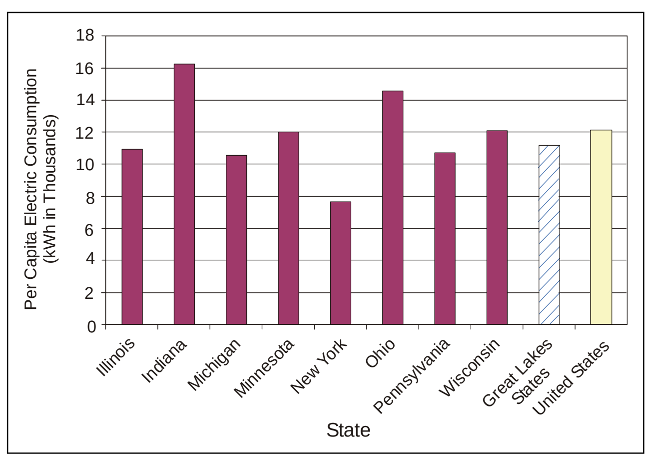

Figure 4. Per capita energy consumption (kWh) by state in the Great Lakes basin, 1999. Data are from Energy Information Administration.
Source: GEM Center for Science and Environmental Outreach, Michigan Technological University

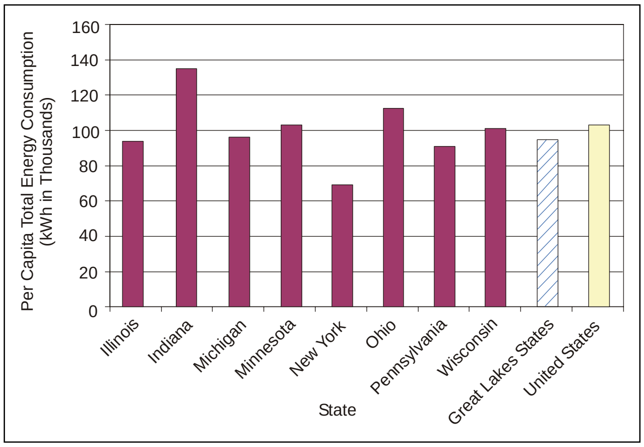

Figure 5. Per capita total energy consumption (kWh) from all sources (coal, natural gas, petroleum, electricity, and other) in the U.S. Great Lakes States, 1999. Data reported in Btu, converted to kWh equivalent. Data are from Energy Information Administration.
Source: GEM Center for Science and Environmental Outreach, Michigan Technological University

desired measure for this indicator, can be calculated only at the state level from EIA energy use tables (Figure 4).

The U.S. Geological Survey reports total power generation and subsets for hydroelectric and thermoelectric (fossil fuel) generation by watershed as part of their national water-use database, updated every five years (http://water.usgs.gov/watuse). The USGS data is convenient because it is already linked to the watersheds that make up the U.S. portion of the Lake Superior basin. However, according to USGS water-use staff, 1995 is probably the last year for watershed-based data to be reported.

For the 15 sub-basins of the U.S. Lake Superior basin, the USGS water-use data shows an increase in total electric power generation, from 3,204 gigawatt-hours (million kilowatt-hours) in 1985 to 3,639 gigawatt-hours in 1990 to 4,719 gigawatt-hours in 1995. Most of that power is thermoelectric; the rest is hydroelectric. The Dead-Kelsey watershed, surrounding Marquette, Michigan, produced 73 percent of the total power all three years. The St. Louis watershed in the Duluth-Superior area added 15 to 18 percent of the total. Both areas serve mines and other large industrial customers. Of the total power generated in the basin, 79 to 86 percent comes from fossil fuel plants. It appears that the USGS data includes only utility power generators, not non-utilities.

The EIA also has state-level per capita energy consumption data for all types of energy by source (coal, natural gas, petroleum, electricity, and other). It might be reasonable to track either total energy consumption for one state, such as Michigan, over time or total energy consumption for each of the Great Lakes states and the U.S. for the same year (Figure 5).

Acknowledgments

Author: Kristine Bradof, GEM Center for Science and Environmental Outreach, Michigan Technological University, MI and James G. Cantrill, Communication and Performance Studies Northern Michigan University, MI.

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U.S. Department of Energy, Energy Information Administration, Form EIA-861, "Annual Electric Utility Report."

Data for utilities within the Lake Superior watershed extracted and energy use per consumer calculated by GEM Center for Science and Environmental Outreach, Michigan Technological University, from 1998 retail electricity sales tables (www.eia.doe.gov/fuelelectric.html).

Per capita electric and total energy use for the U.S. states in the Great Lakes basin were calculated from Table 1.6 "State-Level Energy Consumption, Expenditures, and Prices 1999" (http://www.eia.doe.gov/emeu/aer/txt/tab0106.htm) and Table 10 "Energy Consumption by Source and Total Consumption per Capita, Ranked by State, 1999" (http://ftp.eia.doe.gov/pub/state.data/html/rank10.htm).

Solid Waste Generation

Indicator ID #7060 - Indicator Matrix

Assessment: Mixed

Data from multiple sources are not consistent.

Purpose

To assess the amount of solid waste generated per capita in the Great Lakes basin (GLB), and to infer inefficiencies in human economic activity (i.e. wasted resources) and the potential adverse impacts to human and ecosystem health.

Ecosystem Objective

Solid waste provides a measure of the inefficiency of human land based activities and the degree to which resources are wasted. In order to promote sustainable development, the amount of solid waste generated in the basin needs to be assessed and ultimately reduced. Reducing volumes of solid waste are indicative of a more efficient industrial ecology and a more conserving society. Reduced waste volumes are also indicative of a reduction in contamination of land through landfilling and incineration and thus reduced stress on the ecosystem.

This indicator supports Annex 12 of the Great Lake Water Quality Agreement (GLWQA)

State of the Ecosystem

Canada and the United States are among the highest waste producers on Earth. However, both countries are working towards improvements in waste management by developing efficient strategies to reduce, prevent, reuse and recycle waste generation. Figure 1 displays the average per capita municipal solid waste generation in a selection of some of the most populated municipalities in the Ontario portion of the Great Lakes basin during 1991-2001. From this data, it is evident that there is a continual decline of municipal solid waste generation from 1991 to present. 1991 had the highest per capita generation at a value of 0.681. Per capita solid waste generation declined ~45% in 2001 to a value of 0.373. The rate of per capita municipal solid waste generation appears to have leveled off in the late 1990's. And it must be noted that the apparent increase in per capita generation in 2000 may not be completely accurate since there was less data collected to obtain the average for 2000 as compared to 1999 and 2001. The decline in per capita solid waste generation in the early 1990's can be attributed to the increased access to municipal curbside recycling, backyard and centralized composting programs in most Ontario municipalities.

In addition, Figure 1 displays the average per capita municipal solid waste generation (MSWG) disposed in Minnesota's counties of the Great Lakes basin during 1991-2000. The data shows the amount of MSWG disposed declined slightly from 1991 to 1993, and then increased from 0.386 tonnes per capita in 1994 to 0.436 tonnes per capita in 2000. The data suggests that these trends in MSWG are not significant despite growth in population over the same time period. The counties of Cook, Lake and Pine represent the highest increase of per capita SWG during 1993 to 2000. For example, Cook County in 1993 increased 45% of the municipal SWG.

Figure 1, also displays the average trends of the waste disposed per capita (in tons) in Indiana by estimated county of origin in a final disposal facility. The graphic shows a 21% increase in the per capita of non-hazardous waste disposed between 1992 and 1998. From 1998 to 2000 there was a 9% decrease of the amount disposed.

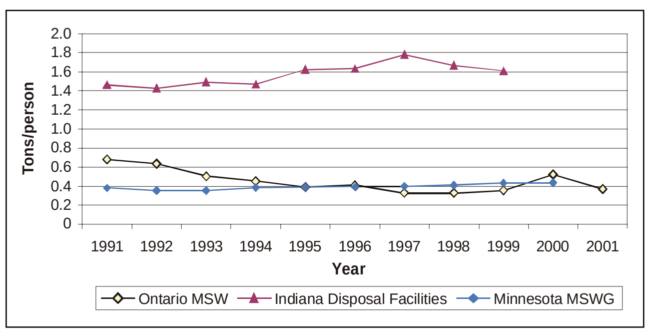

Figure 1. Average per capita solid waste generation and disposal (tons/person) from selected municipalities in Ontario, Indiana and Minnesota, 1991-2001. MSW = Municipal Solid Waste; MSWG = Municipal Solid Waste Generation.

Sources: IDEM-Indiana Department of Environmental Management, 2000; MOEA-Minnesota Office of Environmental Assistance, 2000, Ontario data obtained from Statistics Canada, Environmental Account and Statistics Division, and Demography Division

The Illinois Environmental Protection Agency, Bureau of Land, reported the projected disposal capacity of the solid waste in sanitary landfills for 2000. The regional waste disposed and landfill capacity (in tons) for the Great Lake basin counties was 1.7 percent cubic yards. This area has a per capita capacity below of the state average. The municipal wastes generated and recycled was 7.4 cubic yards.

The Michigan Department of Environmental Quality (DEQ) reports on data of total waste disposed in Michigan landfills in per capita cubic yards from 1996 to 2001. In 1996 the solid waste landfilled per capita was 3.76 cubic yards and in 2001 the value increased to 4.84, showing a 32% increase of solid waste disposed in landfills.

New York Department of Environmental Conservation provided the State SWG data from 1990 to 1998. The data reflects that the average of SWG in per capita from 1990 to 1998 increased a 20% and decreased a 3% from 1995 to 1996. The New York statewide of reusable tons increased approximately 30% of the waste disposed.

The Region 3 of the Environmental Protection Agency in Pennsylvania provided the daily per capita amount of Pennsylvania counties in the GLB of MSW generated. In 1998 the MSW generated for Crawford was 2.4 (pounds/person/day), 3.8 for Erie and 1.4 for Potter. The amount of MSW per capita in 1999 for those counties increased, Crawford had 2.59, Erie 3.73 and Potter 2.64 daily per capita generations. The Department of Environmental Protection (DEP) provided the statewide MSW generation during 1988 to 2000 that increased 30% of the waste disposed.

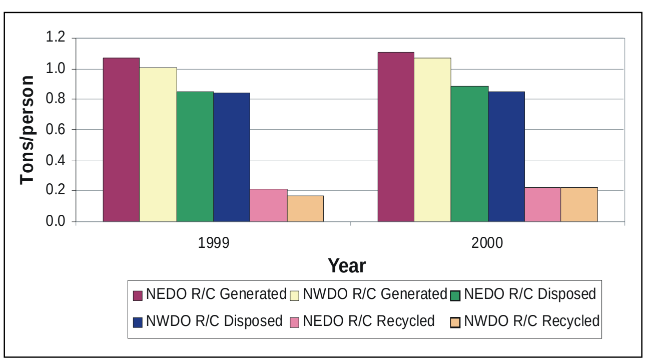

Figure 2. Ohio counties average per capita solid waste landfill facilities generated, disposed and recycled in the Great Lakes basin, 1999-2000.
Source: Ohio Environmental Protection Agency, Division of Solid and Infectious Waste Management

The calculated average per capita municipal waste landfilled in Wisconsin in 2001 was 1.85 tons, as reported by the Department of Natural Resources. The counties with the larger average values are those located closer to the Lake Michigan. For example, Calumet average value is 4.87 tons per person, Dodge is 4.20, Green Lake is 12.11, Kenosha is 3.80 and Manitowoc 4.35 tons per person.

The Ohio Environmental Protection Agency provided the residential and commercial solid waste management district landfill generated, disposed and recycling data according to the 88 counties, which are grouped into 52 single and multi-county districts. The Northeast District Office (NEDO) and the Northwest District Office (NWDO) are districts that include the counties in the Great Lakes basin. Figure 2 presents the average amount of the NEDO and NWDO residential and commercial solid waste management district (SWMD) generated, disposed and recycled for 1999 and 2000. The disposal value of solid waste for NEDO increased 3%. The amount of GSW increased 6% for NWDO over the same time period. The recycled amount increased 2% for NEWO and 32% for NWDO from 1999 to 2000.

Reuse and recycling are opportunities to reduce solid waste levels. By looking at recycling and waste diversion in Ontario, both the tonnage of municipal solid waste diverted from disposal and the number of households with access to recycling have increased in recent years (WDO, 2001c).

Figure 3 shows the trends in residential recycling tonnages in all of Ontario from 1992-2000 (WDO, 2001). From this figure it is evident that there has been a 41% increase in the amount of residential recycling from 1992-2000, which may be accounting for the reduced per capita solid waste generation displayed in recent years in Ontario municipalities.

Future Pressures

The generation and management of solid waste raise important environmental, economic and social issues for North Americans. It costs billions of dollars per

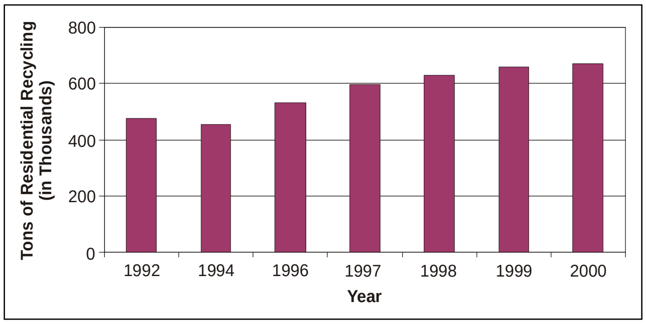

Figure 3. Residential recycling tonnage in Ontario, 1992-2000.
Source: WDO-Ontario Waste Diversion Organization, 2000

are filling up fast. In addition, the generation of municipal solid waste contributes to soil and water contamination and even air pollution etc. It is estimated that far more residential solid waste is being generated each year, but a greater proportion is being recovered for recycling and reuse.

The state of the economy has a strong impact on consumption and waste generation. Waste generation continued to increase through the 1990's as economic growth continued to be strong (US EPA, 2002). Much of this increase in waste generation in the 1990's was due to the booming economy and many people found themselves with a large disposable income (US EPA, 2002). An economic growth results in more products and materials being generated. This growth should send a message for a larger investment in source reduction activities. Source reduction activities will help to save natural resources, it will reduce the toxicity of wastes and it will also reduce costs in waste handling and will make businesses more efficient.

Future Activities
There is a need to assess and determine which material makes up the majority of the municipal solid waste that is generated each year. This will help managers target waste reduction efforts towards limiting the amount of these products that make it through the waste stream. It would also be interesting to research how different waste reduction techniques can produce differing trends in solid waste reduction. For example, user pay, "PAYT" (pay as you throw away) unit-based pricing, is becoming a more acceptable method for financing residential waste management services and making households more directly responsible for their waste generation and disposal habits (WDO, 2001a). Bag limits on waste are usually a first step many municipalities take in order to make the transition to user pay systems easier. User pay programs have gained momentum across most of Canada with most growth occurring in the mid to late 1990's. Imposing these limits encourages homeowners to be more conscious of the amount and type of waste generated as they now associate a financial cost with their consumptive behavior. It makes a homeowner personally responsible and encourages alternative waste diversion activities.

Other examples are an ambitious statewide education campaign dedicated to educate the residents on the benefits of waste reduction and to show them how solid waste can affect their own health and the health of their environment. A local government waste prevention program consisting of a network of counties and cities was organized to discuss and create methods to help in waste reduction activities that would better protect the state's environment and public health. Developing methods for standardizing information and for tracking waste will aid in improving the sharing of information and data statewide.

Further Work Necessary
The province of Ontario has set a challenging task for the WDO to reach a 50% waste diversion. Ontario residents diverted at total of 29% of 1.23 million tones of their residential waste from disposal in 1998. In order to achieve a 50% reduction in waste the following practices need to be encouraged: increased financial support, expand provincial 3R regulations, need to change societal habits and behavior towards waste generation, need to invest more into infrastructure and lastly, the adoption of waste management user fees (WDO, 2001b).

To report on this indicator in the future, data on waste diversion should be incorporated as well as waste generation. Looking at the changes in the amount of waste that is removed from the waste stream can be used to infer how the behavior of society is changing with regards to wasting resources and sustainable development.

During the process of collecting data from this indicator, it was found that most U.S. states and

Ontario municipalities compile and report on solid waste information in different formats. Future work to organize a standardized method of collecting, reporting and accessing data for both the Canadian and U.S. portions of the Great Lakes basin will aid in the future reporting of this indicator.

Acknowledgments:
Authors: Martha I. Avilés-Quintero, USEPA–GLNPO, Chicago, IL and Melissa Greenwood, Environment Canada, Downsview ON.

Ontario data for the disposal of waste by province was obtained from Statistics Canada, Environmental Account and Statistics Division, and Demography Division (http://www.statcan.ca/start.html).
Data collected are based on the values obtained by contacting the waste management departments of Ontario municipalities around the Great Lakes Basin. For any further details regarding specific municipalities, please contact Melissa Greenwood.
The recycling data collected from the province of Ontario, were adapted from the Municipal 3Rs in Ontario: 2000 Fact Sheet, published by the WDO – Ontario Waste Diversion Organization (http:///www.wdo.on.ca).

The United States data of municipal waste generated per capita, average, landfill capacity, disposed and recycled waste were collected by contacting the different State and Federal Agencies managements departments and searching their websites. The U.S. Environmental Protection Agency, Region 5, Pollution Prevention & Program Initiatives Section provided the contact list for the searching values. Some data were adapted using the counties on the Great Lakes basin and using the census-estimate populations to calculate the per capita generation, disposed and recycled.

Illinois data of the Waste Disposed and Landfill Capacity per capita in cubic yards by Region for 2000, was provided by the Illinois Environmental Protection Agency (IEPA), Bureau of Land. The Region 2 is the Chicago Metropolitan basin that included counties on the Great Lakes Basin. (http://www.epa.state.il.us)

Indiana data of the Municipal solid waste per capita for 2001, was offered from Indiana Department of Environmental Management (IDEM). Also, we used the 2000 Summary of Indiana Solid Waste Facility Data Report to calculate the waste disposed per capita. We used the census-estimate population for 1992-2000 by counties on the Great Lakes Basin to obtain those values. (http://www.in.gov.idem/land/sw/index.html)

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Wisconsin data of municipal waste landfill tones capacity for 2001, was provided by Wisconsin Department of Natural Resources (DNR), Bureau of Waste Management. (http://www.dnr.state.wi.us)

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Population Monitoring and Contaminants Affecting the American Otter

SOLEC Indicator #8147 - Indicator Matrix

Assessment: Mixed
Data are not system-wide. Data are from multiple sources.

Purpose
To directly measure the contaminant concentrations found in American otter populations within the Great Lakes basin and to indirectly measure the health of Great Lakes habitat, progress in Great Lakes ecosystem management, and/or concentrations of contaminants present in the Great Lakes. Importantly, as a society we have a moral responsibility to sustain healthy populations of American otter in the Great Lakes/St. Lawrence basin.

Ecosystem Objective
The importance of the American otter as a bio-sentinel is related to IJC Desired Outcomes 6: Biological Community Integrity and Diversity, and 7: Virtual Elimination of Inputs of Persistent Toxic Chemicals. Secondly, American otter populations in the upper Great Lakes should be maintained, and restored as sustainable populations in all Great Lakes coastal zones, lower Lake Michigan, western Lake Ontario, and Lake Erie watersheds and shorelines. Lastly, Great Lakes shoreline and watershed populations of American otter should have an annual mean production of >2 young/adult female; and concentrations of heavy metal and organic contaminants should be less than the NOAEL found in tissue sample from mink as compared to otter tissue samples.

State of the Ecosystem
In a review of State and Provincial otter population data indicates primary areas of population suppression still exist in southern Lake Huron watersheds, lower Lake Michigan and most Lake Erie watersheds. Data provided from New York Department of Environmental Conservation and Ontario Ministry of Natural Resources suggests that otter are almost absent in western Lake Ontario (Figure 1). Most coastal shoreline areas have more suppressed populations than interior zones.

Areas of otter population suppression are directly related with human population centers and subsequent habitat loss, and elevated contaminant concentrations associated with human activity. Little statistically viable population data exists for the Great Lakes populations, and all suggested population levels illustrated were determined from coarse population assessment methods.

Future Pressures
American otters are a direct link to organic and heavy metal concentrations in the food chain. It is a more sedentary species and subsequently synthesizes contaminants from smaller areas. Contaminants are a potential and existing problem for many otter populations throughout the Great Lakes. Globally, indications of contaminant problems in otter have been noted by decreased population levels, morphological abnormalities (i.e. decreased baculum length) and decline in fecundity. Changes in the species population and range are also representative of anthropogenic riverine and lacustrine habitat alterations.

Future Actions
Michigan and Wisconsin have indicated a need for an independent survey using aerial survey methods to index otter populations in their respective jurisdictions. Minnesota has already started aerial population surveys for otter. Subsequently, some presence absence data may be available for Great Lakes watersheds and coastal populations in the near future. In addition, if the surveys are conducted frequently the trend data may become useful.

There was agreement among resource managers on the merits of aerial survey methods to index otter populations. Although, these methods are only appropriate in areas with adequate snow cover.

New York Department of Environmental Conservation, Ohio Department of Natural Resources, Federal jurisdictions and Tribes on Great Lakes coasts indicated strong needs for future contaminant work on American otter.

Funding, other than from sportsmen is needed by all jurisdictions to do habitat, contaminant and aerial survey work.

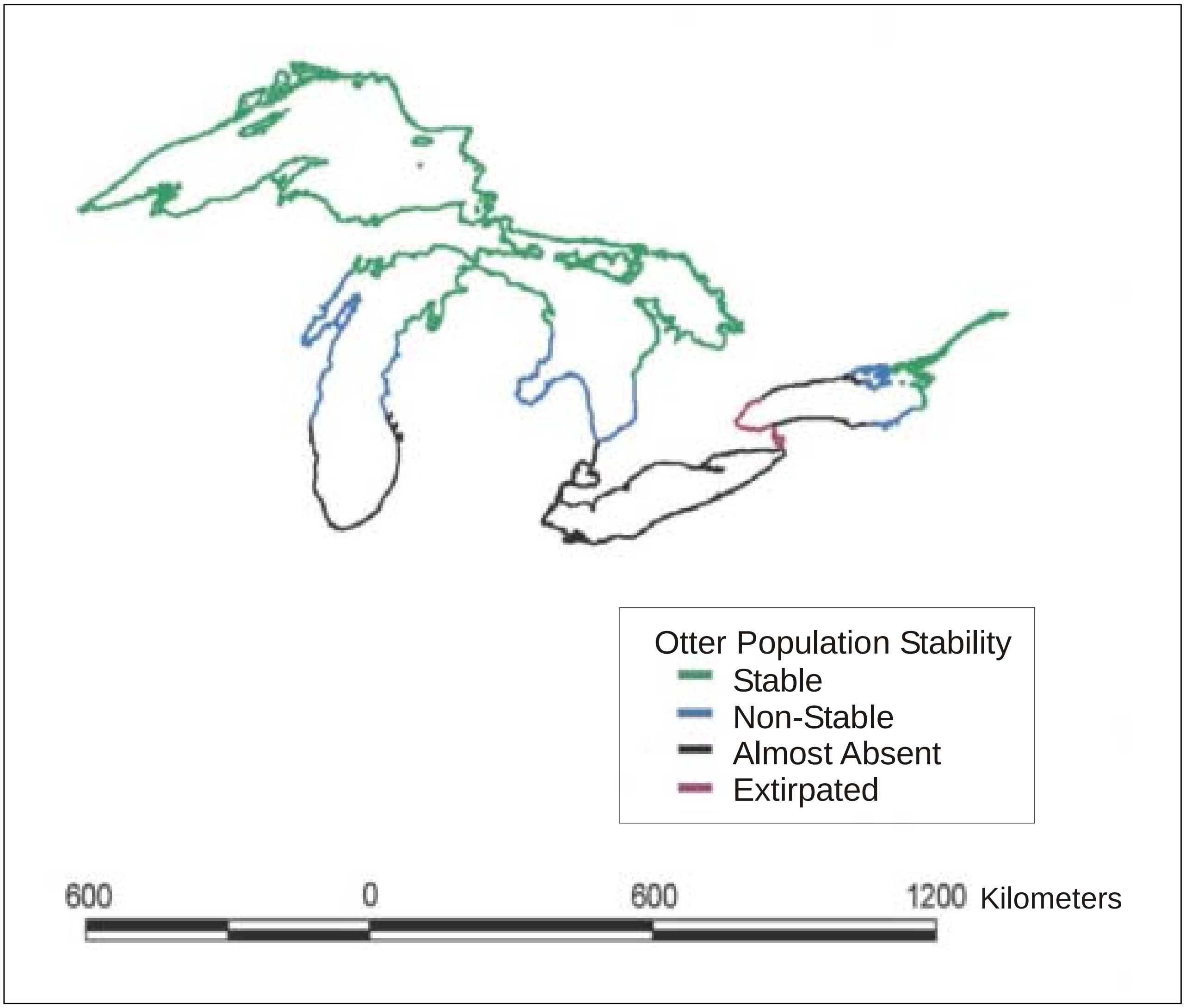

Figure 1. Figure 95. Great Lakes shoreline population stability estimates for the American Otter.
Source: Thomas C.J. Doolittle, Bad River Band of Lake Superior Tribe of Chippewa Indians

Further Work Necessary
All State and Provincial jurisdictions use different population assessment methods making comparisons difficult. Most jurisdictions use survey methods to determine populations on state or provincial wide scales. Most coarse population assessment methods were developed to assure that trapping was not limiting populations and that otter were simply surviving and reproducing in their jurisdiction. There was little work done on finer spatial scales using otter as an indicator of ecosystem heath.

In summary, all State and Provincial jurisdictions only marginally index Great Lakes watershed populations by presence absence surveys, track surveys, observations, trapper surveys, population models, aerial surveys, and trapper registration data.

Michigan has the most useful spatial data that could index the largest extent of Great Lakes coastal populations due to their registration requirements. Michigan registers trapped otter to an accuracy of 1 square mile. However, other population measures of otter health such as reproductive rates, age and morphological measures are not tied to spatial data in any jurisdiction, but are pooled together for entire jurisdictions. If carcasses are collected for necropsy, the samples are usually too small to accurately define health of Great Lakes coastal otter verses interior populations. Subsequently, there is a large need to encourage and fund resource management agencies to streamline data for targeted population and contaminant research on Great Lakes otter populations, especially in coastal zones.

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1.3 Response Indicator Reports

Summary of Response Indicators

The overall assessment for the Response indicators is incomplete. Data presented in this section of the report represent indicators for which information is not available year to year or are not basin-wide across jurisdictions. Within the Great Lakes indicator suite, 38 have yet to be reported, or require further development. In a few cases, indicator reports have been included that were prepared for SOLEC 2000, but that were not updated for SOLEC 2002. The information about those indicators is believed to be still valid, and therefore appropriate to be considered in the assessment of the Great Lakes. In other cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

Indicator Name	Assessment in 2000	Assessment in 2002
Citizen/Community Place - Based Stewardship Activities	No Report	Mixed, improving
Brownfield Redevelopment	Mixed, improving	Mixed, improving
Sustainable Agricultural Practices	Mixed	Not Assessed
Green Planning Process	No Report	Not Assessed

Green represents an improvement of the indicator assessment from 2000.
Red represents deterioration of the indicator assessment from 2000.
Black represents no change in the indicator assessment from 2000, or where no previous assessment exists.

Citizen/Community Place - Based Stewardship Activities

SOLEC Indicator #3513 - Indicator Matrix

Assessment: Mixed Improving
Data are not system-wide. Data from multiple sources are not consistent.

Purpose
To reflect the number, vitality and effectiveness of citizen and community stewardship activities. Community activities that focus on local landscapes/ ecosystems provide a fertile context for the growth of the stewardship ethic and the establishment of a "sense of place."

Ecosystem Objective
Desired objectives are to continue programs supporting protection of the Great Lakes and a sense of community responsibility toward the sustainability of the Great Lakes ecosystem, and to maintain a critical mass of local support for partnerships responsible for setting and maintaining ecosystem health and integrity in places throughout the Great Lakes basin.

State of the Ecosystem
Land trusts and conservancies are a particularly relevant subset of all community-based groups that engage in activities to promote sustainability within the Great Lakes basin because of their direct focus on land and habitat protection. The Land Trust Alliance (LTA) is a national organization in the U.S. dedicated to "promoting voluntary land conservation across the country and providing resources, leadership, and training to the nation's 1,200-plus nonprofit, grassroots land trusts, helping them to protect important open spaces." The LTA's work includes compilation of data from National Land Trust Censuses (NLTC) conducted in 1990 and 2000. The data, organized by state and region, includes number of land trusts, acres protected, and membership.

Data from the NLTC for land trusts that operate at least partly within the U.S. Great Lakes basin show that the number of land trusts increased from 3 in 1930 to 116 in 2000 (Figure 1). Nationwide between

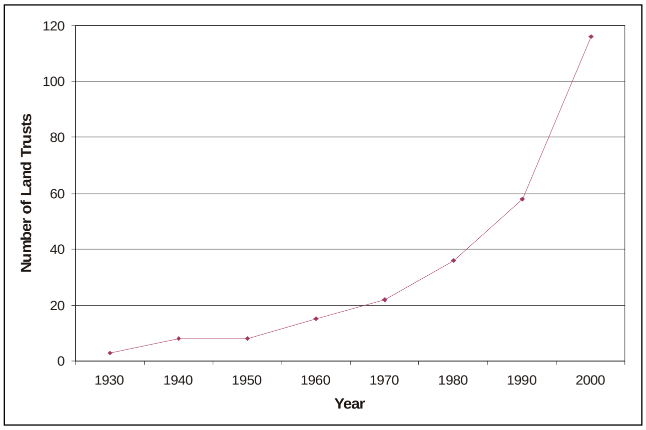

Figure 1. Number of land trusts operating in the U.S. Great Lakes basin, 1930-2000. Data provided by the Land Trust Alliance and land trust websites.
Source: GEM Center for Science and Environmental Outreach, Michigan Technological University

1950 and 2000, the number of land trusts increased from 53 to 1,263. During the same period in the Great Lakes basin, the number of land trusts increased from 8 to 116. The number of land trusts doubled between 1990 and 2000 in the Great Lakes region, compared to a 42% increase nationally.

The total area protected by land trusts within the basin more than doubled between 1990 and 2000 from 177,077 to 397,784 acres (Figure 2). (These figures do not include acres owned by national organizations, such as The Nature Conservancy, which protected 111,725 acres in the Great Lakes basin as of February 2002.) Nationally, protected land increased from 1,908,547 acres to 6,479,672 acres, according to the LTA.

The Centre for Land and Water Stewardship at the University of Guelph reported the results of a national survey of Canadian land trusts, also known as nature trusts or conservancies, 30 of which are located in Ontario (Watkins 2001). The first land trusts were established in Canada in the 1960s, much later than in the U.S., in response to the increasing loss of natural landscapes, pressures of urban development, and intensifying resource consumption. Much of the increase in the number of land trusts occurred in the 1990s. For example, between 1998 and 2000, the number of land trusts in Canada increased from 60 to 82. Fifty-eight (70 percent) responded to the summer 2000 survey, including 24 in Ontario. Most of the Ontario land trusts are located in southern Ontario and, therefore, probably in the Great Lakes basin. The 24 Ontario land trusts own 7,775 acres and protect an additional 794 acres through conservation easements. The survey excludes land protected by the Nature Conservancy of Canada, which totals 82,700 acres in 545 Ontario properties acquired between 1962 and 1999. Of that total, 19,268 acres are protected through ownership, 505 acres through conservation easements, and 62,927 acres through financial assistance, stewardship support, or other means. In 1999, 26 more properties were acquired, adding 11,130 acres.

Since first authorized by the Ontario legislature in 1946, 38 community-based Conservation Authorities (CAs), 32 of them in the Great Lakes basin, have played a unique and vital role in managing natural resources, which includes holding lands in the public trust. The Conservation Authorities Act of 1946 provided for local communities to establish watershed-based CAs with projects undertaken in financial partnership with the Province. Conservation Ontario, the CA network, reports that as of 2000, Conservation Authorities owned and managed 352 conservation areas totaling 340,000 acres (138,000 hectares).

Future Pressures
As more land is developed, land trusts will continue to play an important role in permanently protecting natural habitat and "open space" through direct

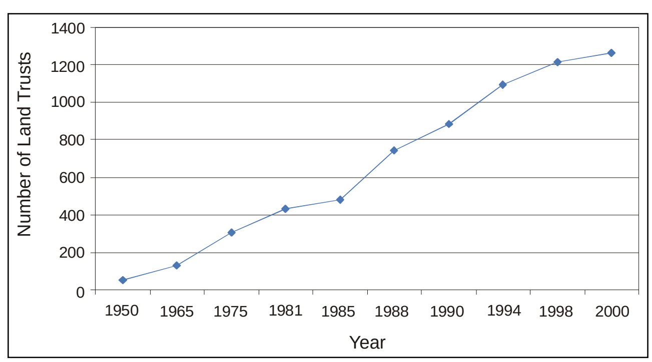

Figure 2. Land trusts operating in the Great Lakes basin, 1950-2000. Data provided by the Land Trust Alliance and land trust websites.
Source: GEM Center for Science and Environmental Outreach, Michigan Technological University

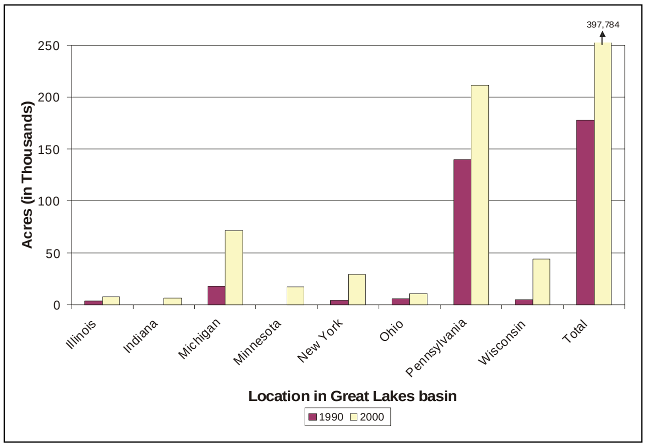

Figure 3. Acres protected by land trusts in the U.S. Great Lakes basin, 1990-2000. Data provided by the Land Trust Alliance and land trust websites.
Source: GEM Center for Science and Environmental Outreach, Michigan Technological University

ownership and/or management, holding of conservation easements, transfer of lands to government or other entities, purchase of development rights, and other means. Other community organizations, such as watershed councils and groups focused on trails, conservation issues, and environmental advocacy, will encourage more sustainable management of public and private lands and direct public attention to areas where critical habitat or other important environmental values may be lost without safeguards.

Future Activities

Reporting on the activities of community organizations that promote various aspects of sustainability within the Great Lakes basin is likely to encourage more such activity. In addition to conducting the National Land Trust Census, the LTA also tracks ballot initiatives across the country to assess voter support for referenda that encourage land acquisition to preserve open space, which could be another useful measure for this indicator. It appears likely that the LTA will continue this monitoring, so that SOLEC will not have to obtain data independently. Data quality can be checked against websites or by direct inquiries to the land trusts. The Ontario Land Trust Alliance (OLTA), formerly the Ontario Nature Trust Alliance, has links to land trusts and conservancies in the Great Lakes basin area of the province and appears to be taking on a similar role to LTA, so they may be able to provide similar data in the future. Most of the organizations contacted were quite willing to provide data, so it would make sense in the future to work with them to meet SOLEC's needs, as well as their own. This indicator should be evaluated in conjunction with preserves, parks, and forests in public ownership because many privately acquired and managed sites are eventually transferred to public entities.

Further Work Necessary

A new indicator under consideration at SOLEC 2002, "Community and First Nation Engagement in Great Lakes Protection and Decision-Making," would incorporate elements of the current indicator 3513 and others in an attempt to clarify and reduce the number of societal indicators. Overall, the data reported here should be reasonably accurate, but some questions remain. For example, some land trusts listed in the 1990 NLTC were not listed in 2000; some were not land trusts, some no longer exist, while others have merged or changed names. Some land trusts in the NLTC existed in 1990 but LTA was not aware of them. In the first case, 1990 land trusts, acreage, and membership may be overrepresented; in the latter, they may be underrepresented. The NLTC also doesn't include The Nature Conservancy and other similar national organizations, which have provided data separately for analysis. Some land trusts have operating areas only partly in the Great Lakes Basin, so their acreages may be overestimated (though this is less problematic when comparing trends over time). Some of those organizations provided a Great Lakes basin-specific breakdown of their protected areas, which increase the accuracy of the acreage reported. Minor discrepancies between the census data and websites or communications from land trusts regarding the year the organization was founded may alter Figure 1 slightly. Directories of natural resources, environmental, and outdoor recreation organizations can supply additional data for this indicator.

Acknowledgments

Author: Kristine Bradof, GEM Center for Science and Environmental Outreach, Michigan Technological University, in consultation with Laurie Payne of Lura Consulting regarding the relationship of this indicator to a new indicator proposed for consideration at SOLEC 2002.

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Rob Aldrich of the Land Trust Alliance provided a subset of data from the 1990 and 2000 National Land Trust Censuses for the Great Lakes basin. Renee Kivikko, Jennifer Adkins, and Geri Angeles of LTA's Midwest, Mid-Atlantic, and Northeast Programs, respectively, checked the author's listings of land trusts at least partly in the Great Lakes Basin. Many other individuals provided more detailed information about their organizations and holdings in the Great Lakes basin that aided in the interpretation of the reported data.

Christen Mcginnes of The Nature Conservancy national office provided data on managed areas within counties at least partly in the Great Lakes basin. The following TNC staff provided assistance in interpreting the data from their respective states: Doug Lehr (Illinois), Fiona Solkowski (Indiana), Tom Duffus (Minnesota), Ross Lebold (Ohio), and Nicole Van Helden (Wisconsin).

Melissa Watkins of the Centre for Land and Water Stewardship, University of Guelph, sent information on Ontario land trusts from their 2002 survey of land trusts in Canada. Dan Knaus of the Nature Conservancy of Canada provided data on that organization's Ontario land holdings. Some information about Ontario Conservation Authorities was found on the Conservation Ontario website (http://www.conservation-ontario.on.ca/) and websites of individual Conservation Authorities.

Brownfields Redevelopment

Indicator ID #7006 - Indicator Matrix

Assessment: Mixed Improving
Data from multiple sources are not consistent.

Purpose
To assess the acreage of redeveloped brownfields, and to evaluate over time the rate at which society remediates and reuses former developed sites that have been degraded or abandoned.

Ecosystem Objective
The goal of brownfields redevelopment is to remove threats of contamination associated with these properties and to bring them back into productive use. Remediation and redevelopment of brownfields results in two types of ecosystem improvements:

1. reduction or elimination of environmental risks from contamination associated with these properties; and
2. reduction in pressure for open space conversion as previously developed properties are reused.

State of the Ecosystem
All eight Great Lakes states, Ontario and Quebec have programs to promote remediation or "cleanup" and redevelopment of brownfields sites. Several of the brownfields cleanup programs have been in place since the mid to late 1980s, but establishment of more comprehensive brownfields programs that focus on remediation and redevelopment has occurred during the 1990s. Today, each of the Great Lakes states has a voluntary cleanup or environmental response program. These programs offer a range of risk-based, site-specific background and health cleanup standards that are applied based on the specifics of the contaminated property and its intended reuse.

Efforts to track brownfields redevelopment are uneven among Great Lakes states and provinces. Not all jurisdictions track brownfields activities and methods vary where tracking does take place. Most states track the amount of funding assistance provided as well as the number of sites that have been redeveloped. These are indicators of the level of brownfields redevelopment activity in general, but they do not necessarily reflect land renewal efforts (i.e., acres of land redeveloped)-the desired measure for this SOLEC indicator. Adding up state and provincial information to come up with a brownfields figure that represents the collective eight states and two provinces is challenging at best. Several issues are prominent. First, state and provincial cleanup data reflect different types of cleanups, not all of which are "brownfields" (e.g. some include leaking underground storage tanks and others do not). Second, some jurisdictions have more than one program, and not necessarily all relevant programs engage in such tracking. Third, program figures do not include cleanups that have not been

Figure 1. Figure 98. Brownfield site in Detroit, Michigan, 1998.
Source: Victoria Pebbles, Great Lakes Commission

part of a state or provincial cleanup program (e.g. local or private cleanups). That said, several states and provinces do track acres of brownfields remediated, although no Great Lakes state or province tracks acres of brownfields redeveloped.

Information on acres of brownfields remediated from Illinois, Minnesota, New York, Ohio, Pennsylvania and Quebec indicate that, as of August, 2002, a total of 32,103 acres have been remediated in these states and provinces alone, and approximately 4,600 acres were remediated between 2000-2002. Available data from eight Great Lakes states and Quebec indicates that more than 24,000 brownfields sites have participated in brownfields cleanup programs since the mid-1990s, although the degree of "remediation" varies considerably.

Remediation is a necessary precursor to redevelopment. Remediation is often used interchangeably with "cleanup," though brownfields remediation does not always involve removing or treating contaminants. Many remediation strategies utilize either engineering or institutional controls (also known as exposure controls) or adaptive reuse techniques that are designed to limit the spread of, or human exposure to, contaminants left in place. In many cases, the cost of treatment or removal of contaminants would prohibit reuse of land. All Great Lakes states and provinces allow some contaminants to remain on site as long as the risks of being exposed to those contaminants are eliminated or reduced to acceptable levels. Capping a site with clean soil or restricting the use of groundwater are examples of these "exposure controls" and their use has been a major factor in advancing brownfields redevelopment. Several jurisdictions keep track of the number and location of sites with exposure controls, but monitoring the effectiveness of such controls occurs in only three out of the ten jurisdictions.

Redevelopment is a criterion for eligibility under many state brownfields cleanup programs. Though there is inconsistent and inadequate data on acres of brownfields remediated and/or redeveloped, available data indicate that both brownfields cleanup and redevelopment efforts have risen dramatically in the mid 1990s and steadily since 2000. The increase is due to risk-based cleanup standards and the widespread use of state liability relief mechanisms that allow private parties to redevelop, buy or sell properties without being liable for contamination they did not cause. Data also indicates that the majority of cleanups in the Great Lakes states and provinces are occurring in older urbanized areas, many of which are located on the shoreline of the Great Lakes and in the basin. Based on the available information, the state of brownfields redevelopment is *mixed-improving*.

Future Pressures

Laws and policies that encourage new development to occur on undeveloped land instead of on urban brownfields, are significant and ongoing pressures that can be expected to continue. Programs to monitor, verify and enforce effectiveness of exposure controls are in their infancy, and the potential for human exposure to contaminants may inhibit the redevelopment of brownfields.

Several Great Lakes states allow brownfields redevelopment to proceed without cleaning up contaminated groundwater as long as no one is going to use or come into contact with that water. However, where migrating groundwater plumes ultimately interface with surface waters, some surface water quality may continue to be at risk from brownfields contamination even where brownfields have been remediated.

Future Activities

Programs to monitor and enforce exposure controls need to be fully developed and implemented. More research is needed to determine the relationship between groundwater supplies and Great Lakes surface waters and their tributaries. Because brownfields redevelopment results in both reduction or elimination of environmental risks from past contamination and reduction in pressure for open space conversion, data should be collected that will enable an evaluation of each of these activities.

Further Work Necessary

Great Lakes states and provinces have begun to track brownfields remediation and or redevelopment, but the data is generally inconsistent or not available in ways that are helpful to assess progress toward meeting the terms of the Great Lakes Water Quality Agreement. Though some jurisdictions have begun to implement web-based searchable applications for users to query the status of brownfields sites, the data gathered are not necessary consistent, which presents challenges for assessing progress in the entire basin. States and provinces should develop common tracking methods and work with local jurisdictions incorporating local data to an online data bases that can be searched by: 1) acres remediated; 2) mass of contamination removed or treated (i.e., not requiring an exposure control); 3) type of treatment; 4) geographic location; 5) level of urbanization; and 6) type of reuse (i.e., commercial, residential, open, none, etc).

Acknowledgments
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email: vpebbles@glc.org, web: www.glc.org, with assistance from Becky Lameka and Kevin Yam, Great Lakes Commission, Ann Arbor, MI.

Sources
Selected Annual Reports of state cleanup programs.

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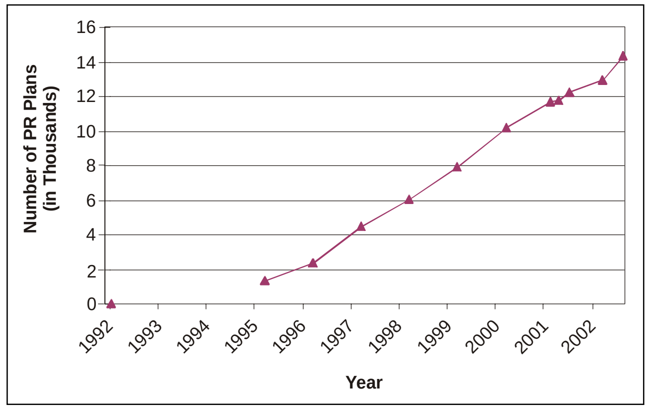

Figure 1. Ontario Environmental Farm Plans (EFP) Peer-reviewed (PR) Plans, 1995-August 2002. The linear trend line indicates a steady increase in the number of Peer Reviewed Plans per year. EFP RP plans identify on-farm environmental risks and develop action to remediate risks.
Source: Ontario Soil and Crop Improvement Association and Ontario Ministry of Agriculture and Food, 2002

Sustainable Agriculture Practices

SOLEC Indicator #7028 - Indicator Matrix

Assessment: Not assessed

Data from multiple sources are not consistent.

Purpose
To assess the number of Environmental and Conservation farm plans and environmentally friendly practices in place such as: integrated pest management to reduce the potential adverse impacts of pesticides; conservation tillage and other soil preservation practices to reduce energy consumption and sustain natural resources and to prevent ground and surface water contamination.

Ecosystem Objective
This indicator supports Annex 2, 3, 12 and 13 of the GLWQA. The objective is the sound use and management of soil, water, air, plant, and animal resources to prevent environmental degradation. The process integrates natural resource, economic, and social considerations to meet private and public needs. The goals are to create a healthy and productive land base that sustains food and fiber, sustains functioning watersheds and natural systems, enhances the environment and improves the rural landscape.

State of the Ecosystem
Agriculture accounts for 35% of the land area of the Great Lakes basin and dominates the southern portion of the basin. In the past there were higher amounts of conventional tillage, a lack of crop rotations and land management practices that were not environmentally responsible. These practices resulted in soil erosion and poor water quality. These practices also lead to high amounts of nutrients/ pesticide losses that contributed to sedimentation of major tributaries that mouth into the Great Lakes.

A survey of pesticide use in Ontario (1998) estimates quantities of active ingredient used on all Ontario crops equivalent to 1/5 of the total for the Great Lakes Basin (26,000 tons) of pesticide used annually. Excessive amounts of conventional tillage practices and application of pesticides without regard for Integrated Pest Management principles contribute to declines in soil organic matter and poor water quality.

Recently, increased cooperation with the farm community in the Basin on Great Lakes water quality management programs has resulted in a 38% reduction in U.S. erosion rates over the last several decades. The overall reduced risk of water erosion on Canadian Great Lakes cropland also shows a positive trend resulting primarily from shifts toward conservation tillage and more environmentally responsible cropping and land management practices. The adoption of more environmentally responsible practices has helped to replenish carbon in the soils back to 60% of turn-of-the-20th. Century levels. More cooperative work is needed, especially for intensive row crop or horticultural crop production and areas of vulnerable topography or soil.

Both the Ontario Ministry of Agriculture and Food (OMAF) and the USDA's Natural Resources Conservation Service (NRCS) provide conservation planning advice, technical assistance and incentives to farm clients and rural landowners. Clients develop and implement conservation plans to protect, conserve and enhance natural resources that harmonize farm productivity, business objectives and the environment. Successful implementation of conservation planning depends upon the voluntary participation of clients.

The Ontario Environmental Farm Plan (EFP) encourages farmers to develop action plans and adopt environmentally responsible technologies through the Ontario Farm Environmental Coalition (OFEC) workshops delivered in partnership with OMAF and the Ontario Soil and Crop Improvement Association. As part of Ontario's Clean Water Strategy, the recently passed Nutrient Management Act (June 2002) The Ontario Nutrient Management Act, passed in June 2002 will provide regulations for new and expanding large livestock operations to address key water and environmental protection objectives. The USDA's Environmental Quality Incentives Program provides technical, educational, and financial assistance to landowners that install conservation systems and the Conservation Reserve Program allows landowners to convert environmentally sensitive acreage to vegetation cover. An Ontario program–Greencover-with similar objectives to the U.S. Quality Incentives program is currently under development.

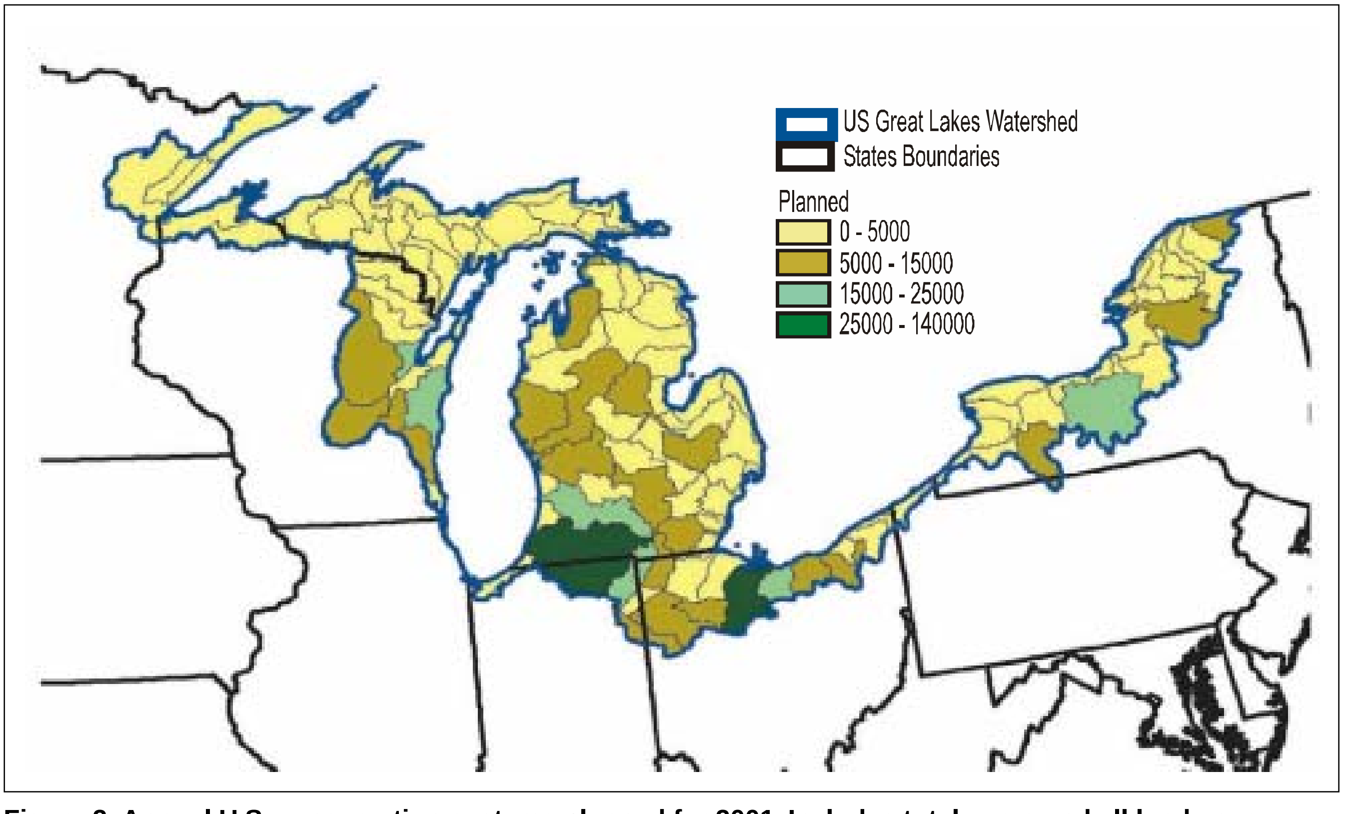

Figure 2. Annual U.S. conservation systems planned for 2001. Includes total acres and all land uses.
Source: USDA, NRCS, Performance and Results Measurement System

USDA's voluntary Environmental Quality Incentives Program provides technical, educational, and financial assistance to landowners that install conservation systems. The Conservation Reserve Program allows landowners to convert environmentally sensitive acreage to vegetative cover. States may add funds to target critical areas under the Conservation Reserve Enhancement Program. The Wetlands Reserve Program is a voluntary program to restore wetlands.

Future Pressures

The trend towards increasing farm size and concentration of livestock will change the face of agriculture in the basin. Development pressure from the urban areas may increase the conflict between rural and urban landowners. This can include pressures of higher taxes, traffic congestion, flooding and pollution. By urbanizing farmland, we may limit future options to deal with social, economic, food security and environmental problems.

Future Actions

In June 2002 the Canadian Federal government announced a multi-billion Agricultural Policy Framework (APF). The goal for this comprehensive policy is for Canada to be a world leader in food safety, innovation and environmentally responsible production. As part of the APF framework the Canadian Government announced a $100 million commitment over a 4-year period (starting 2003) for farmers to help Canadian farmers increase implementation of Environmental Farm Plans. The estimated commitment to Ontario represents at least $20–23 million for these purposes. Ontario is developing a Best Management Practices (BMP) book for Buffers. The Ontario Ministry of Agriculture and Food is undergoing a program evaluation of Food Systems 2002–a comprehensive program to reduce pesticides in food production by 50% started in 1987. Pesticide use surveys, conducted every 5 years since 1983, are scheduled for 2003. Partnerships between agriculture and municipalities include incentives for BMP's to reduce phosphorus loading and protect rural water quality.

The U.S. Clean Water Action Plan of 1998 calls for the USDA and the USEPA to cooperate further on soil erosion control, wetland restoration, and reduction of pollution from farm animal operations. National goals are to install 2 million miles of buffers along riparian corridors by 2002 and increase wetlands by 100,000 acres annually by 2005. Under the 1999 EPA/USDA Unified National Strategy for Animal Feeding Operation (AFO) all AFOs will have comprehensive nutrient management plans implemented by 2009.

Acknowledgments

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Green Planning Process

SOLEC Indicator #7053 - Indicator Matrix

Assessment: Not Assessed.

Data are not consistent, not long-term, not system-wide.

Purpose

To assess the number of municipalities with environmental and resource conservation management plans in place, and to infer the extent to which municipalities utilize environmental standards to guide their management decisions with respect to land planning, resource conservation, and natural area preservation. Given that not all municipalities have planning departments, planning commissions, or zoning ordinances—much less "green" management plans—the number and percentage of municipalities with those features will also be documented, as will planning programs and statutes at the state and provincial level.

Ecosystem Objective

Planning processes to support sustainable development should be adopted by all governmental units in the Great Lakes basin to minimize adverse ecosystem impacts. This indicator supports Annex 13 of the Great Lakes Water Quality Agreement.

Progress toward this ecosystem objective falls into the "Mixed" assessment category, as discussed further under Future Pressures.

State of the Ecosystem

An American Planning Association (APA) survey, known as *Planning for Smart Growth: 2002 State of the States*, confirms that state planning reforms and "smart growth" measures were top state concerns between 1999 and 2001 (http://www.planning.org/growingsmart/states2002.htm). The APA divides states into four categories reflecting the status of smart growth planning reforms. Twelve U.S. states, including Wisconsin and Pennsylvania, are credited with implementing moderate to substantial statewide comprehensive planning reforms. New York is the only Great Lakes state among the ten states that are strengthening local planning requirements or improving regional or local planning reforms already adopted. Illinois, Michigan, and Minnesota are among the fifteen states actively pursuing their first major statewide smart growth planning reforms. Ohio and Indiana are among the thirteen states that have not yet begun to pursue significant statewide planning reforms.

The report identifies eight consistent trends in statewide planning reform. (1) Implementation of planning reforms is challenging. (2) Most successful reforms have a governor or legislator as a political champion. (3) Linking reforms to quality-of-life issues is key. (4) Coalitions and consensus promote planning reforms. (5) Reforms sometimes lead to backlash. (6) Task forces are often the starting point for planning reforms. (7) Some areas, particularly in the West, use ballot initiatives to initiate reforms. (8) Piecemeal reforms are politically more popular than comprehensive ones. While recognition of the hidden costs of unmanaged growth has spurred the revision of outdated planning and zoning laws, funding for implementation remains a problem.

The Province of Ontario is conducting a five-year review of the 1996 Provincial Policy Statement (PPS) on land use planning to "determine whether Ontario's land use planning policies are consistent with Smart Growth: the government's strategy for promoting and managing growth in ways that sustain a strong economy; build strong communities; and promote a healthy environment" The PPS's three major policy areas are (1) managing change and promoting efficient, cost-effective development and land-use patterns that stimulate economic growth and protect the environment and public health, (2) protecting resources for their economic use and/or environmental benefits, and (3) reducing the potential for public cost or risk to Ontario's residents by directing development away from areas where there is a risk to public health or safety, or of property damage. Public comments on the PPS indicate that it is generally sound, but suggest that some revisions be considered (www.mah.gov.on.ca/userfiles/page_attachments/1830857_Five-Year-e.pdf). However, the Canadian Environmental Law Association (CELA) and Federation of Ontario Naturalists criticize both the Ontario Provincial Policy Statement and the five-year review process (www.cela.ca/Intervenor/26_4/26_4pps.htm). Among the problems with the PPS is the lack of comprehensive data or performance indicators to assess the effectiveness of the policy.

The Conservation Council of Ontario (CCO) has produced its own "GreenOntario" vision statement (www.greenontario.org/smartgrowth/index.html) and a comparison chart with the government's vision for Smart Growth (www.smartgrowth.gov.on.ca), which the CCO feels places much more emphasis on economic growth than on healthy communities and environment. The CCO cites the Ontario Professional Planners Institute (OPPI) policy paper, *Exploring Growth Management Roles in Ontario: Learning From "Who Does What Elsewhere"* (September 2001) as providing excellent guidelines and case studies (www.ontarioplanners.on.ca/policy.html).

A positive trend in recent years is planning based on regional-scale natural features, such as the Niagara Escarpment and Oak Ridges Moraine in Ontario. University of Waterloo's Assessment and Planning Project evaluates the usefulness of the 1985 Niagara Escarpment Plan (NEP), the first large-scale environmental land use plan in Ontario and in Canada, as a model for future environmentally sensitive land-use planning. The NEP's main purpose is to preserve and protect environmental features while allowing compatible development (http://ersserver.uwaterloo.ca/ asmtplan/ontariomain.html). The NEP has received two five-year reviews, the most recent in 2001, at which time CELA noted "the growing consensus that the NEP is sound as it is, so 'if it ain't broke, don't fix it.'" (www.cela.ca/Intervenor/26_1/26_Icone.htm). The purpose of the Niagara Escarpment Commission (NEC), established in 1973 under the Niagara Escarpment Planning and Development Act, is to "provide for the maintenance of the Niagara Escarpment and land in its vicinity substantially as a continuous natural environment and ensure only such development occurs as is compatible with that natural environment" (www.escarpment.org/Commission/comission_about.htm). In addition to the NEC, the Coalition on the Niagara Escarpment (CONE), an umbrella group of 30 environmental organizations formed in 1978, monitors development on the Escarpment in coordination with local communities (www.niagaraescarpment.org/page_about_cone.html). Twelve local municipalities and the Regional Municipality of Niagara also collaborated on a 2001 report, "Smart Growth in Niagara" to guide development in the region (http://www.regional.niagara.on.ca/admin/smartgrowth/pdf/Smart_Growth_in_Niagara.pdf).

The Oak Ridges Moraine Conservation Act, passed in December 2001, and the subsequent Oak Ridges Moraine Conservation Plan are ecologically based measures "established by the Ontario Government to provide guidance and direction for the 190,000 hectares of land and water within the Moraine" north of Toronto (www.mah.gov.on.ca/oakridgesmoraine/ormplannov12001-e.pdf). Rivers that flow south to Lake Ontario have their headwaters on the Moraine. "A continuous band of green rolling hills that provides form and structure to south-central Ontario, while protecting the ecological and hydrological features and functions that support the health and well-being of the region's residents and ecosystems" is the official vision for the Moraine. That vision is shared by a number of grassroots organizations concerned about the implementation of the plan, given the intense development pressure in the region (www.greenontario.org/strategy/orm.html).

Conservation Authorities (CAs), community-based environmental protection and resource planning agencies that function within watershed boundaries, are another example of planning and resource management based on ecosystem features. First authorized by the Conservation Authorities Act in 1946, the 38 Ontario CAs today manage watersheds

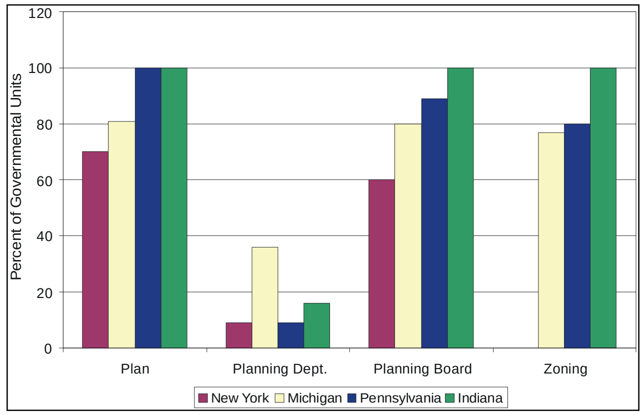

Figure 1. Percentage of governmental units, within selected areas of the Great Lakes basin, that have any of the following features: a comprehensive plan, a professional planner or planning department, a citizen planning board or commission, and a zoning ordinance.
Source: Western New York Regional Information Network of the University at Buffalo, Michigan Sea Grant, Nathan Zieziula of the Crawford County (Pennsylvania) Planning, Eric Randall of the Erie County (Pennsylvania) Department of Planning, Don Reitz of Allen County (Indiana) Department of Planning

that are home to 90 percent of the provincial population. Project costs are shared by member municipalities and the provincial government. A CA is established by request of local communities that agree to run the organization.

The following are some examples of data obtained from municipalities in parts of the U.S. Great Lakes basin for this project. Crawford County, Pennsylvania, has a professional planning office and planning commission but no countywide zoning. Its 2000 comprehensive plan, which replaces the 1973 version, reflects Pennsylvania's new "Growing Greener" policy. The plan addresses a variety of green features, such as developing greenways and concentrating development near existing services and in clusters to preserve open space. Of the seven townships and boroughs within the county that are at least partly within the Great Lakes basin, none have planning departments or staff, four have planning commissions, but all have land use or comprehensive plans (most adopted between 1970 and 1981). Five have zoning ordinances and enforcement officers and all have floodplain ordinances. Neighboring Erie County is served by the Erie Area Council of Governments, which coordinates planning among the county, the City of Erie and 6 of the 26 townships and boroughs that are at least partly in the basin. Only the City and County of Erie have planning departments but all jurisdictions except one have planning commissions and all but four have zoning and floodplain ordinances. All have land use or comprehensive plans, 13 of which have been adopted or revised in the last five years. Details on the green features of the plans are limited, but 7 address open space and growth focused near existing services, while 14 have provisions for farmland protection and 23 address stormwater and erosion control. Basic planning and zoning data from these counties plus areas of three other states are summarized in Figure 1.

	1994	2002
Cities	69.8%	95.3%
Villages	66.7%	86.7%
Townships	49.6%	76.1%
Counties	53.3%	73.3%
State	55.7%	80.6%

Figure 2. Michigan coastal jurisdictions that have adopted master plans, 1978-2002.
Source: Western New York Regional Information Network of the University at Buffalo, Michigan Sea Grant, Nathan Zieziula of the Crawford County (Pennsylvania) Planning, Eric Randall of the Erie County (Pennsylvania) Department of Planning, Don Reitz of Allen County (Indiana) Department of Planning

A December 2002 report from Michigan Sea Grant, *Status of Planning and Zoning in Michigan's Great Lakes Shoreline Communities*, documents an increasing number of governmental units with master plans (Figure 2). However, the survey of 338 counties and sub-county jurisdictions "does not provide details about the quality of local land management efforts." The report notes regional variations in the amount of shoreline that is covered by master plans or zoning ordinances. For example, only about 40 percent of Lake Superior's shoreline is covered by some sort of county-level master plan, and sub-county jurisdictions provide minimal additional coverage. In the Northern Lake Huron and Lake Superior regions, less than 25 percent of coastal communities have professional planning staff, below the statewide average of about 36 percent.

Future Pressures
Sprawl is no longer a problem limited to urban and suburban areas, so the increased emphasis on planning even in rural areas, where it has often been nearly nonexistent until recently, is encouraging. Planning and zoning officials are certainly taking into account a variety of Best Management Practices and regulatory issues. Nonetheless, this indicator receives a "Mixed" assessment because of the following limitations on progress, among others: too little emphasis on implementation of agreed-upon planning goals, lax enforcement, too few resources, and too great a willingness to make exemptions in the name of development. For example, most watershed initiatives still struggle to influence local governmental planning processes and often don't receive line-item financing (though the soft money seems to keep coming along).

Future Activities
The efforts of groups such as the American Planning Association, its state affiliates, and a variety of nonprofit organizations and educational institutions to provide resources and training for "smart growth" and sustainable development are positive signs. The APA compiled summaries of state planning laws in 1996 and 2002, so similar future assessments are likely. State governments are also enacting laws and developing programs in these areas. Some states, such as Wisconsin, now mandate comprehensive planning at the local level and encourage coordinated planning among neighboring communities through enabling legislation and grant programs.

Many communities now encourage local residents, not just appointed planning commissioners, to participate in land use visioning sessions and reviews of planning documents. Increasingly, local units of government have websites with links to planning and zoning departments or boards and sometimes to public documents, such as comprehensive plans (or drafts for public review) and zoning ordinances, that are available online. Some counties, such as Cayuga in New York, have encouraged this trend by hosting websites for cities, towns, and villages.

Further Work Necessary
The information presented here is from a preliminary analysis of parts of the Great Lakes basin for which some planning and zoning information was either available on the Internet or provided by regional or

county planning staff. The most significant limitation on obtaining data for this indicator in many areas of the basin is the lack of regional or statewide attempts to gather information on the extent and quality of planning and zoning processes at the local level. Such information would also be a first step toward coordinating efforts among jurisdictions, essential to achieving ecosystem-sensitive planning. Most regional planning agencies contacted for this project to date expressed interest in having such data but did not have the staff time or funding required to compile it. Others are limited to transportation planning activities only.

This project developed spreadsheets to gather basic information about planning departments and commissions or boards, zoning ordinances and officials or boards to administer them, and comprehensive or master plans in place. Additional columns addressed particular "green" features of plans, programs, or ordinances, such as cluster development, wellhead protection, mixed-use zoning, and environmental corridors, and purchase or transfer of development rights. The spreadsheets were organized by state, regional planning agency (if applicable), county, and local unit of government. It was hoped that regional planning agencies could either fill out the surveys themselves or refer them to the local units of government, but the response was discouraging because most of them did not have the information. Some forwarded the survey forms, but only one was filled out and returned.

The most reliable means of obtaining data relevant to the green planning indicator, though a time-intensive one, appears to be searching websites and following up for details as needed with the contact persons listed. However, that method does not address municipalities that lack websites. No mention of planning and zoning on a website also doesn't mean that they don't exist within the community. Another approach to data acquisition, also time intensive, is to survey a random sample of the local governments within the basin and follow up as necessary to obtain the information. Although these limitations are likely to persist to some degree, more information in electronic form should be available in the future as its value and the need for access to it become more apparent.

Acknowledgments
Authors: Kristine Bradof, GEM Center for Science and Environmental Outreach, Michigan Technological University; and James Cantrill, Professor of Communication and Performance Studies at Northern Michigan University and U.S. co-chair, Developing Sustainability Committee, Lake Superior Work Group, Lake Superior Binational Program.

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Western New York Regional Information Network of the University at Buffalo (State University of New York, http://rin.buffalo.edu/s_envi/envi.html). New York data reflects 6 city, 37 town, 22 village, and 3 tribal governments in Erie and Niagara Counties.

Michigan Sea Grant, 2002. Status of Planning and Zoning in Michigan's Great Lakes Shoreline Communities (www.miseagrant.umich.edu/pubs/pdf/Klep_survey.pdf). Michigan data is from the 72 cities, 190 townships, 25 villages, and 50 counties that border the Great Lakes.

Nathan Zieziula of the Crawford County (Pennsylvania) Planning Commission added details to the survey form, supplementing information from the Comprehensive Plan Phase II: Plan Elements for Crawford County, Pennsylvania 1997-2000 (http://www.co.crawford.pa.us/Planning/ftp/comprehensiveplan.pdf) and other pages on www.co.crawford.pa.us.

Eric Randall of the Erie County (Pennsylvania) Department of Planning filled out the planning survey and provided a listing of "Municipal Planning and Development Controls, Updated April 2002," which contains dates of comprehensive plans and zoning and stormwater management ordinances. The Pennsylvania data represent Crawford and Erie Counties and the 1 city, 22 towns, and 10 boroughs in the Great Lakes basin portion of those counties.

Don Reitz of Allen County (Indiana) Department of Planning Services filled out the survey for the 25 local units of government in the Great Lakes basin part of the county (3 cities, 17 townships, and 4 towns).

Section 2
Proposed Changes to the Great Lakes Indicator Suite

The list of Great Lakes indicators that are reported through the SOLEC process is open to improvement. Some indicators may be found to be not as useful as anticipated and therefore dropped from the list. Some may be changed to reflect better metrics or data availability. Still others may be added to assess ecosystem components that had not been previously included. For example, efforts are continuing to define and refine indicators to assess the condition of Great Lakes forests and ground water.

The indicator reports that follow in this section were prepared to accompany descriptions for proposed indicators presented at the State of the Great Lakes Conference in October, 2002. These reports have been prepared and formatted according to the same guidelines used for the other indicators, except no Assessment was made. The indicators themselves, however, have not yet been fully vetted through the SOLEC indicator selection process.

Reports are included for the following proposed indicators:

2.1 Societal Response Indicators
- Commercial / Industrial Eco-Efficiency Measures
- Cosmetic Pesticide Controls

2.2 Agriculture Indicators
- Nutrient Management Plans
- Integrated Pest Management

2.3 Groundwater Indicators
- Base Flow Due to Groundwater Discharge
- Natural Groundwater Quality and Human-Induced Changes
- Water Use and Intensity

2.4 Other Indicators
- Contaminants in Whole Fish
- Status of Sturgeon in the Great Lakes
- External Anomaly Prevalence Index (EAPI) for Nearshore Fish

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 which 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.

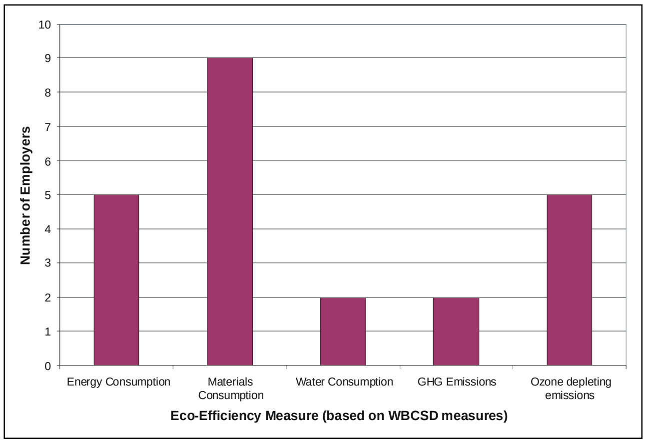

Figure 1. Number of the 25 largest employers in the Great Lakes basin that publicly report eco-efficiency measures. WBCSD = World Business Council for Sustainable Development GHG = green house gas.
Source:

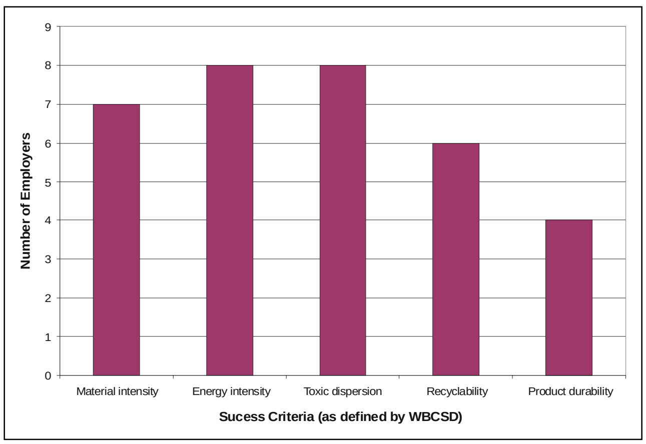

Figure 2. Number of the 25 largest employers in the Great Lakes basin that publicly report initiatives related to eco-efficiency success criteria. WBCSD - World Business Council for Sustainable Development.
Source:

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.

Acknowledgments
Author: Laurie Payne, LURA Consulting. Contributors: Christina Forst, Oak Ridge Institute for Science and Education, on appointment to U.S. Environmental Protection Agency, Great Lakes National Program Office, 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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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…"[1] 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 more regulations in the U.S. in the near future. Cleveland Heights, Ohio is one municipality that has banned the use of pesticides on publicly owned lands and on private property in the city.[2] 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

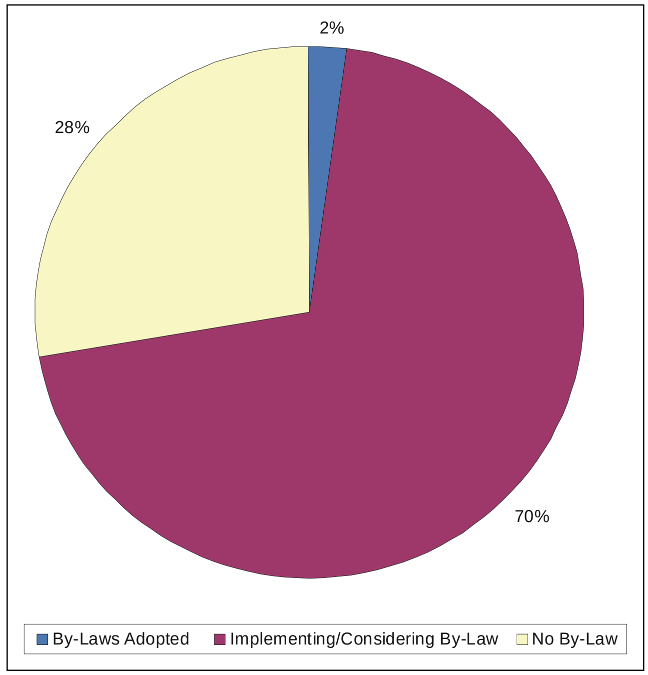

Figure 1. Ontario and Quebec municipalities in the pesticide reduction process. The total number of municipalities: 2,184.
Source

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.

Further 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 or 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.

Acknowledgments

Author: Christina Forst, Oak Ridge Institute for Science and Education, on appointment to U.S. Environmental Protection Agency, Great Lakes National Program Office, forst.christina@epa.gov, Contributors: Laurie Payne, LURA Consulting/ Environment Canada.

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2.2 AGRICULTURAL INDICATORS

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 bylaws), 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 U.S. 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 bylaws that reflect local concerns yet highlight the need for standardization. Such standardization will be a part of the regulation development process in Ontario's Nutrient Management Act.

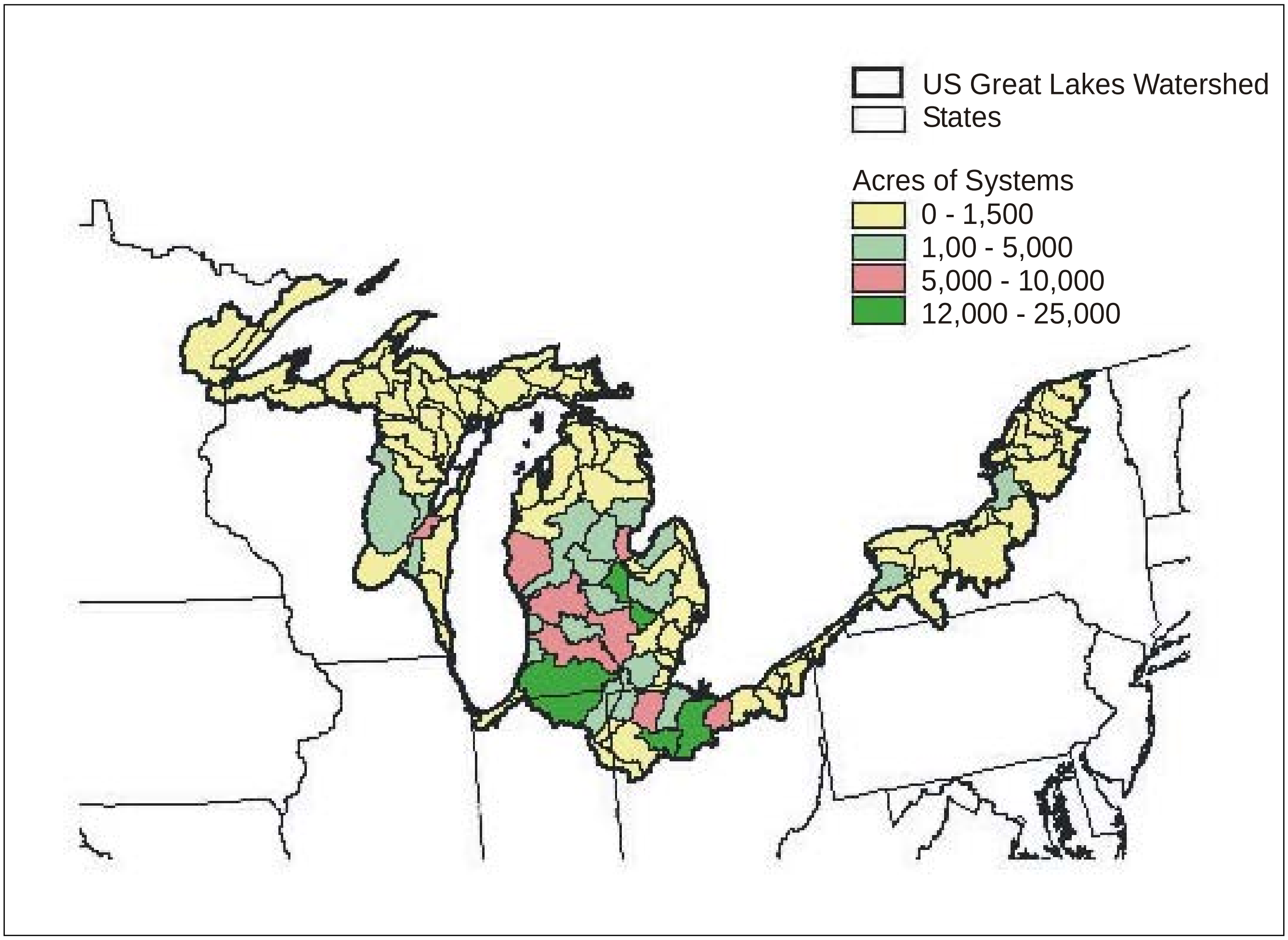

Figure 1. Annual U.S. nutrient management systems planned for the 2001 fiscal year.
Source: USDA, NRCS, Performance and Results Measurement System

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

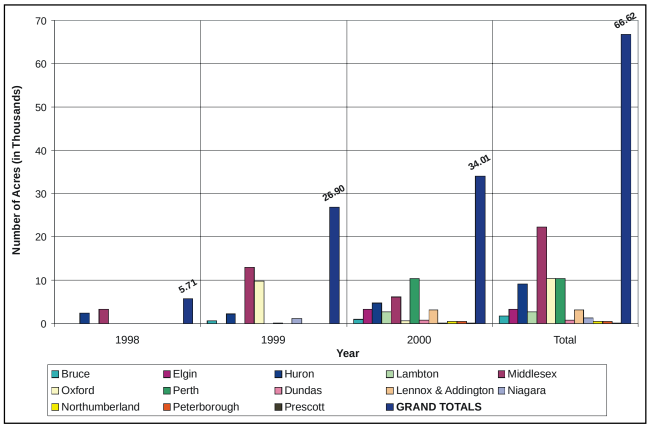

Figure2. Nutrient management plans by Ontario Counties, 1998-2000.
Source:

tool box" for nutrient management plans in place in Ontario. The phasing in requirements of province-wide standards for nutrient management planning 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 minimize 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, Water Quality Specialist, USDA-Natural Resources Conservation Service, ruth.shaffer@mi.usda.gov, and Roger Nanney, Resource Conservationist, USDA, NRCS, Roger.Nanney@in.usda.gov, Peter A. Roberts, Agriculture and Rural Division, Environmental Management Specialist-Water Management, peter.roberts@omaf.gov.on.caand Jean Rudichuk, OMAF, Guelph, Ontario.

Integrated Pest Management (sample report)
New Indicator

Purpose
A goal for agriculture is to become more sustainable through the adoption of more nonpolluting, 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.

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 U.S. 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

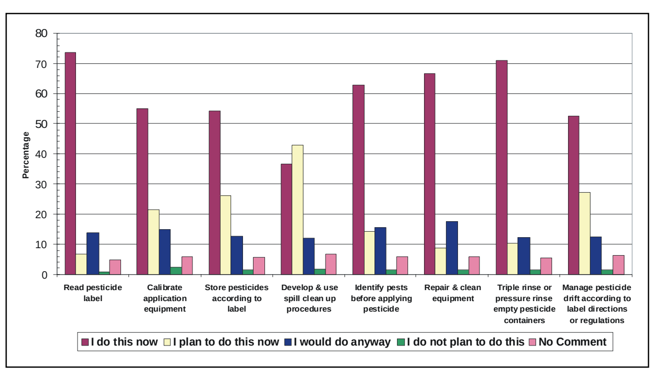

Figure 1. Grower pesticide safety course evaluation results, 2000-2001.
Source: Ontario Ministry of Agriculture & Food and the University of Guelph

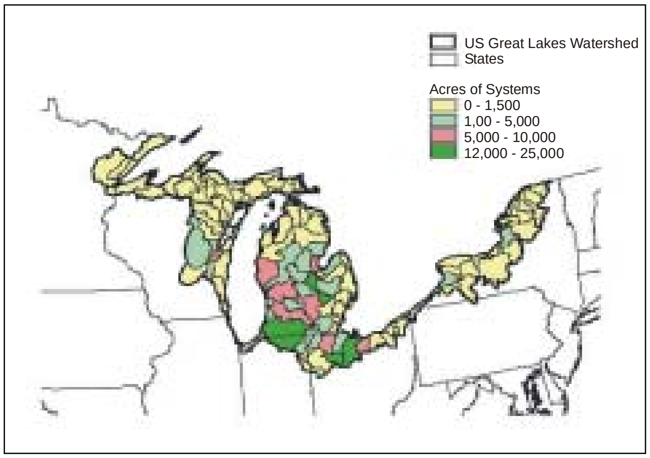

Figure 2. Annual U.S. nutrient management systems planned for the 2001 fiscal year.
Source: USDA, NRCS, Performance and Results Measurement System

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.

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, Water Quality Specialist, USDA-Natural Resources Conservation Service, ruth.shaffer@mi.usda.gov, and Roger Nanney, Resource Conservationist, USDA, NRCS, Roger.Nanney@in.usda.gov, Peter A. Roberts, Agriculture and Rural Division, Environmental Management Specialist-Water Management, peter.roberts@omaf.gov.on.ca and Jean Rudichuk, OMAF, Guelph, Ontario.

2.3 Groundwater Inidcators

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.

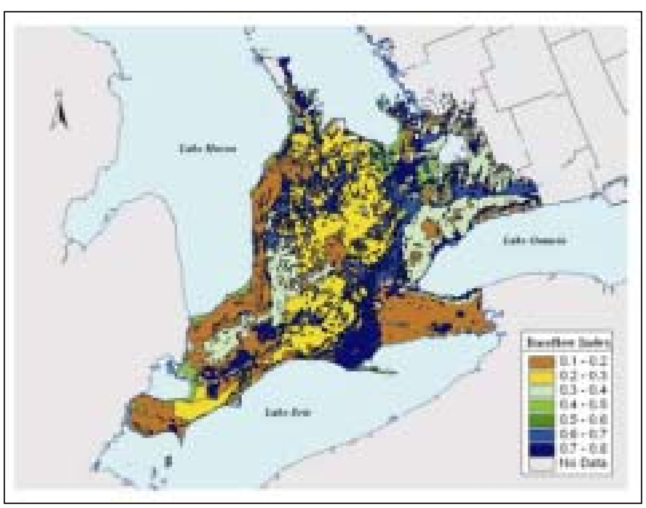

Figure 1. Base flow index based on geology.
Source: Piggott *et al.*, 2002

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 2,700ft3/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 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.

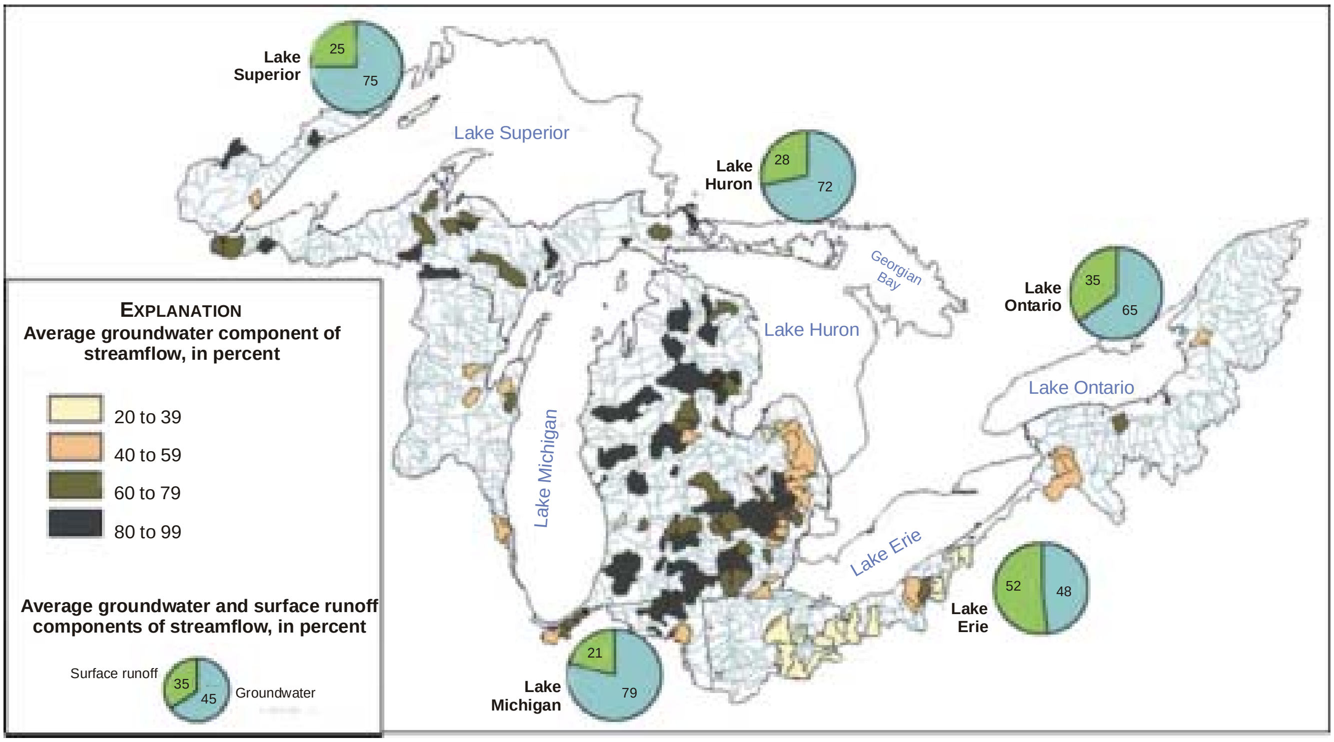

Figure 3. Base flow component of streamflow.
Source: Grannemann *et al.*, 2000

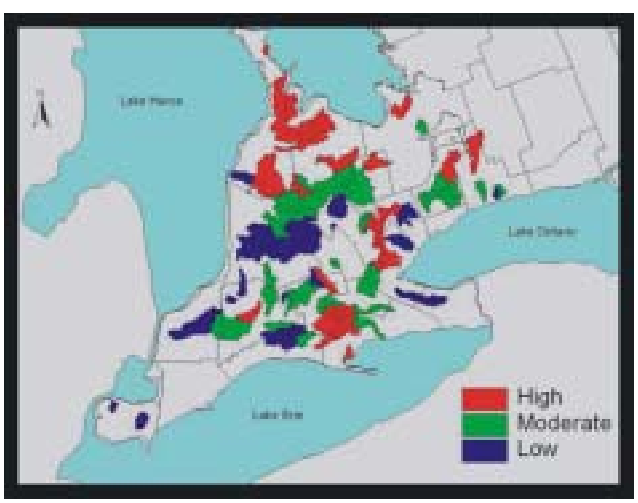

Figure 2. Base flow index calculated from stream gauge measurements.
Source: Piggott *et al.*, 2001

Future 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.

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

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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 50µg/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.

Groundwater contamination has been shown to be most prevalent in shallow groundwater less than 100 feet below agricultural and urban areas. In a

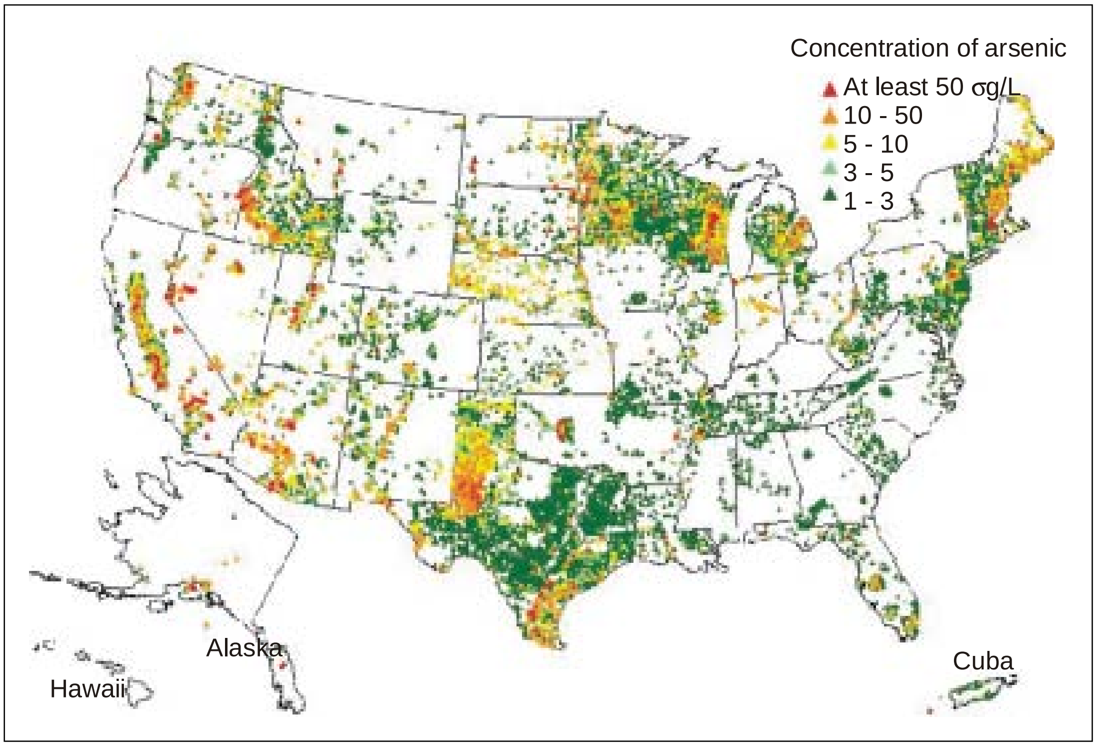

Figure 1. Concentrations of arsenic found in groundwater of the United States.
Source: USGS

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 esticide 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. 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

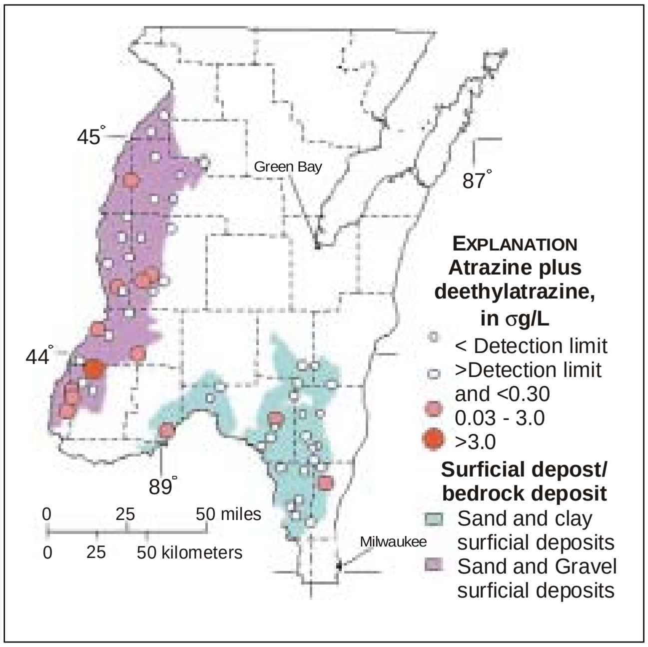

Figure 2. Atrazine concentrations found in shallow groundwater. Highest concentrations found in areas with the most permeable surficial deposits.
Source: USGS Circular 1156, 1998.

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.

Acknowledgments
Author: Cheryl Martin, International Joint Commission, Windsor.

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

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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

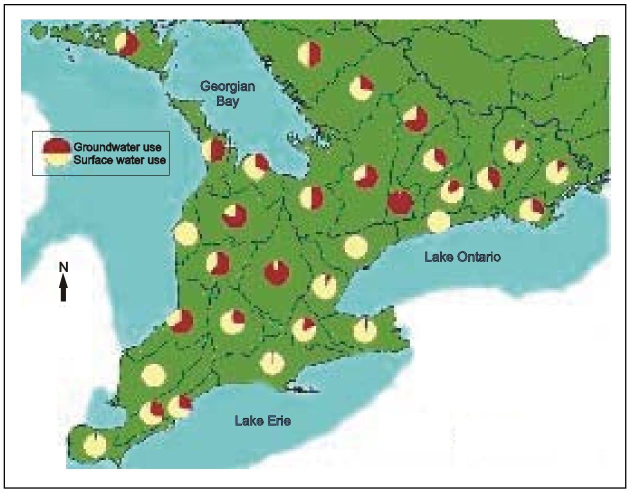

Figure 1. Percentage of surface and groundwater use in Southern Ontario watersheds.
Source: Environment Canada, Water Use and Supply Project

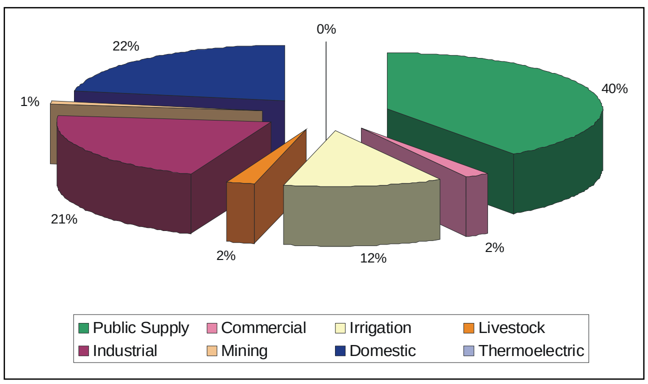

Figure 2. Percentage of groundwater use by sector for Michigan, 1995.
Adapted from: Solley *et al.*, 1998

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.

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.

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.

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,

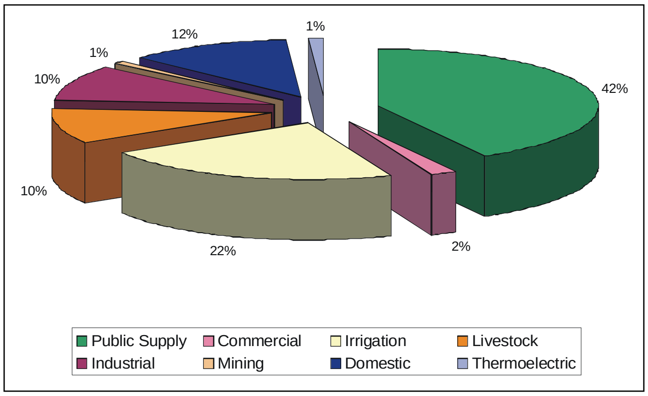

Figure 3. Percentage of groundwater use by sector for Wisconsin, 1995.
Adapted from: Solley *et al.*, 1998

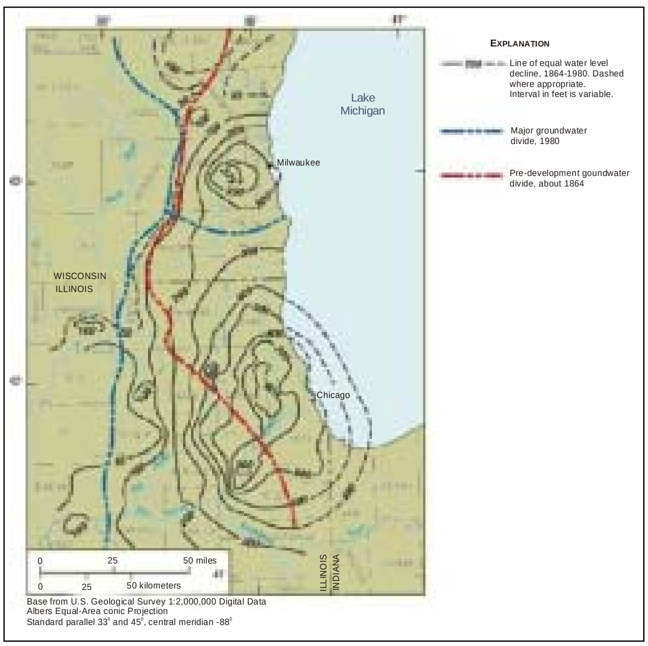

Figure 4. Changes to groundwater in the Chicago area, 1864-1980.
Source: Grannemann *et al.*, 2000

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.

Acknowledgments

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

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2.4 Other Proposed Indicators

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 are 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 annually 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, 2, 3, 4). Levels of both PCBs and ΣDDT in smelt samples have declined significantly through 2001 since the most recent peak in 1997 (Figs. 5 & 6). Concentrations of Hg in smelt populations have remained virtually unchanged since 1985 (Fig. 7).

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 ΣDDT levels were observed in 2001 lake trout samples (4^+ - 6^+) (Fig. 3). 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. 2, Fig. 8). The Canadian data shows that ΣDDT 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 ΣDDT levels approximately 23% of levels recorded in 1988 (Fig. 4). Total PCB and ΣDDT levels in smelt peaked in 1990 and 1989 respectively (Figs. 5 & 6). 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. 7).

Lake Huron: The U.S. data shows that PCBs in similarly sized fish have steadily declined through 2001 (Fig. 2). 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. 4). 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 & 3). 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. 5 & 6). 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. 7).

Lake Michigan: PCB and ΣDDT levels in lake trout have declined consistently through 2000 (Figs. 2 & 4). 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 & 2). 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. 2). 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. 4). 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 3). 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 5). Over the period 1981 to 2000, ΣDDT concentrations observed in smelt populations have remained unchanged since a significant decline occurred in 1984 (Fig. 6). 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 7). 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

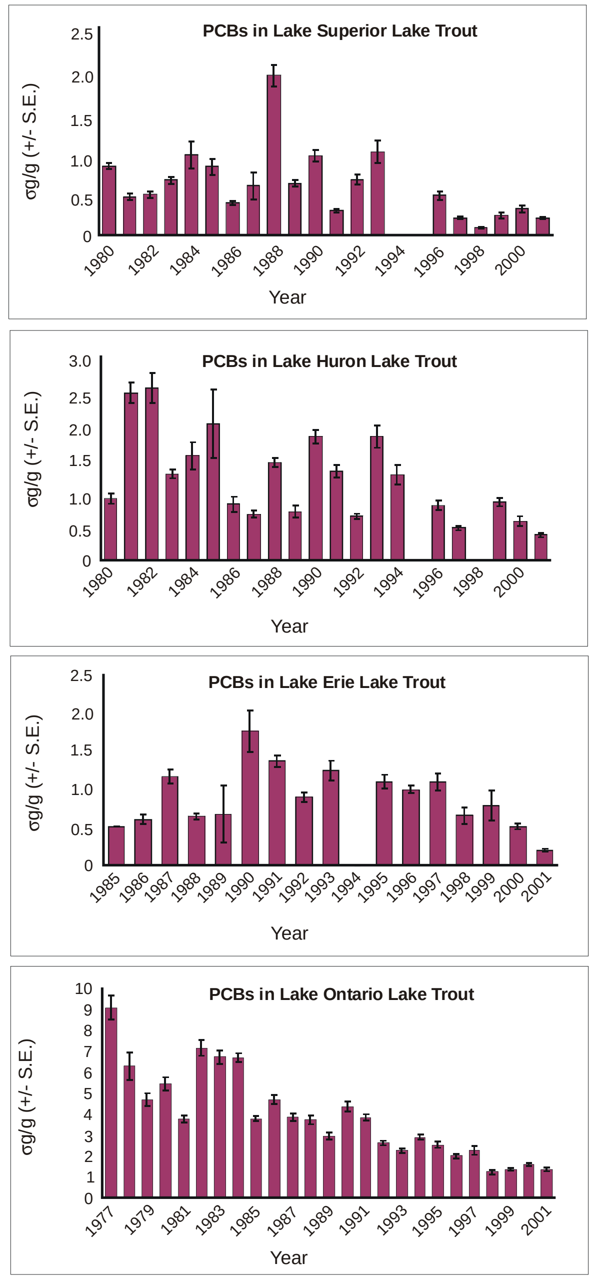

Figure 1. Total PCB levels in whole Lake Trout, 1977-2001. Canadian data µg/g wet weight +/- S.E., age 4^+ - 6^+ years. Note the different scales between lakes.
Source: Department of Fisheries and Oceans Canada

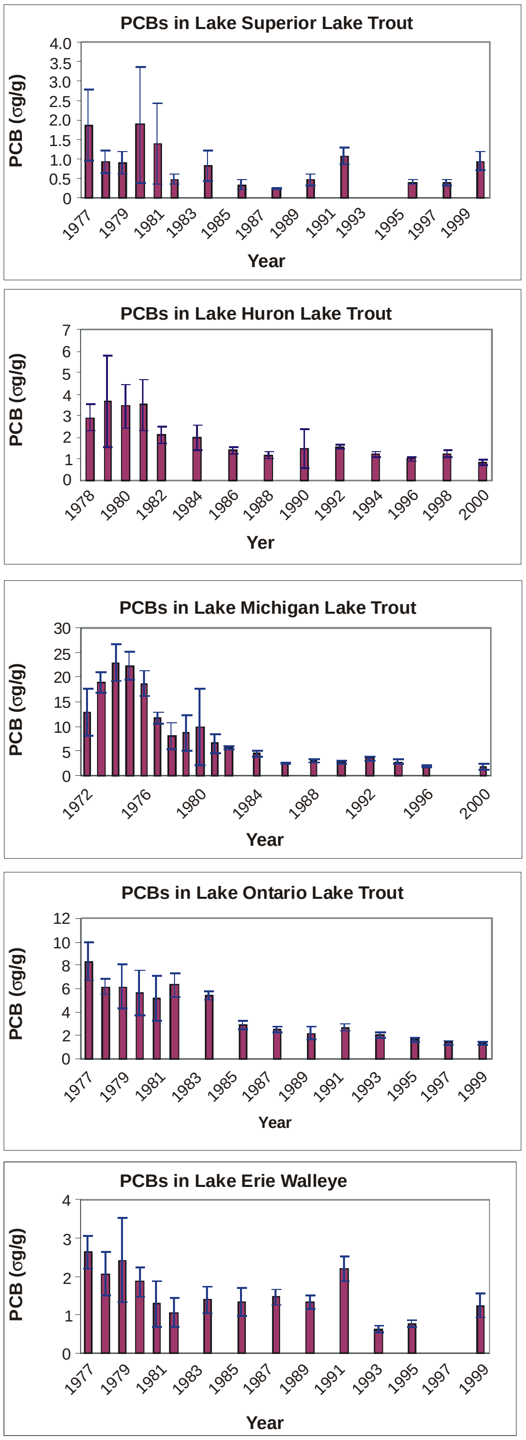

Figure 2. PCB levels in whole Lake Trout, 1977-2001. µg/g wet weight +/- 95% C.I., composite samples, 600-700mm size range. Lake Erie data are for walleye in the 400-500mm size range. Note the different scales between lakes.

Source: U.S. Environmental Protection Agency

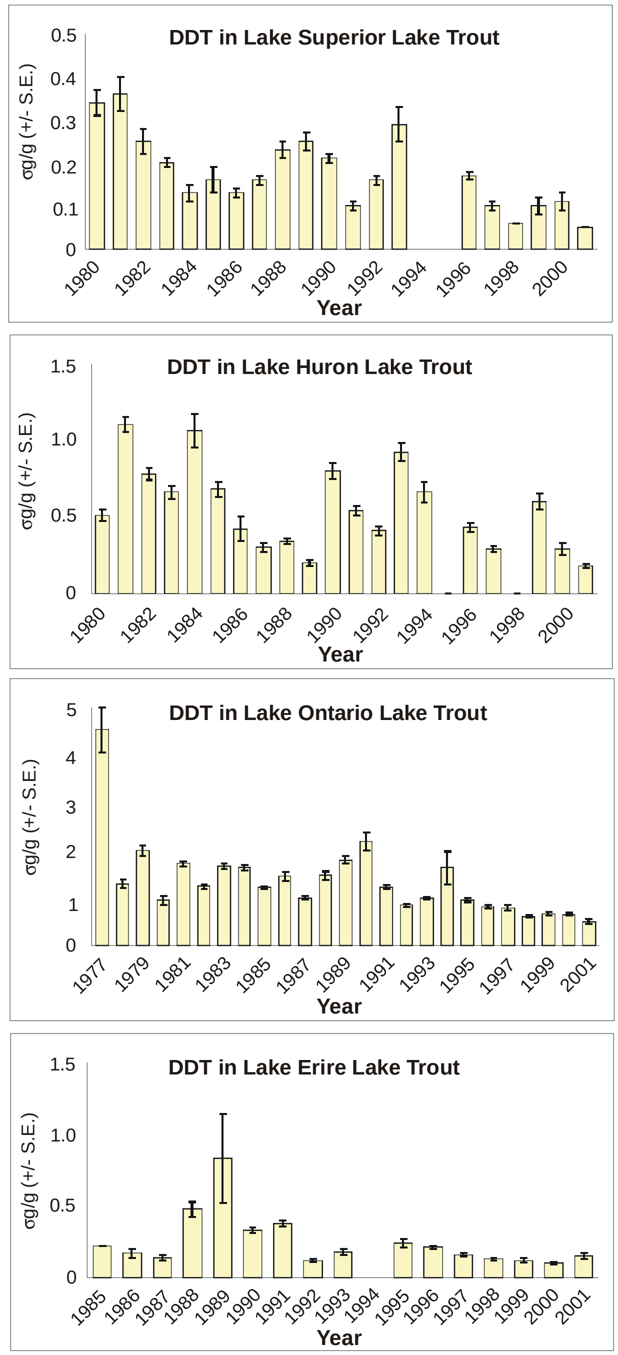

Figure 3. Total DDT levels in whole Lake Trout, 1977-2001. Canadian data µg/g wet weight +/- S.E., age 4^+ - 6^+ years. Note the different scales between lakes.

Source: Department of Fisheries and Oceans Canada

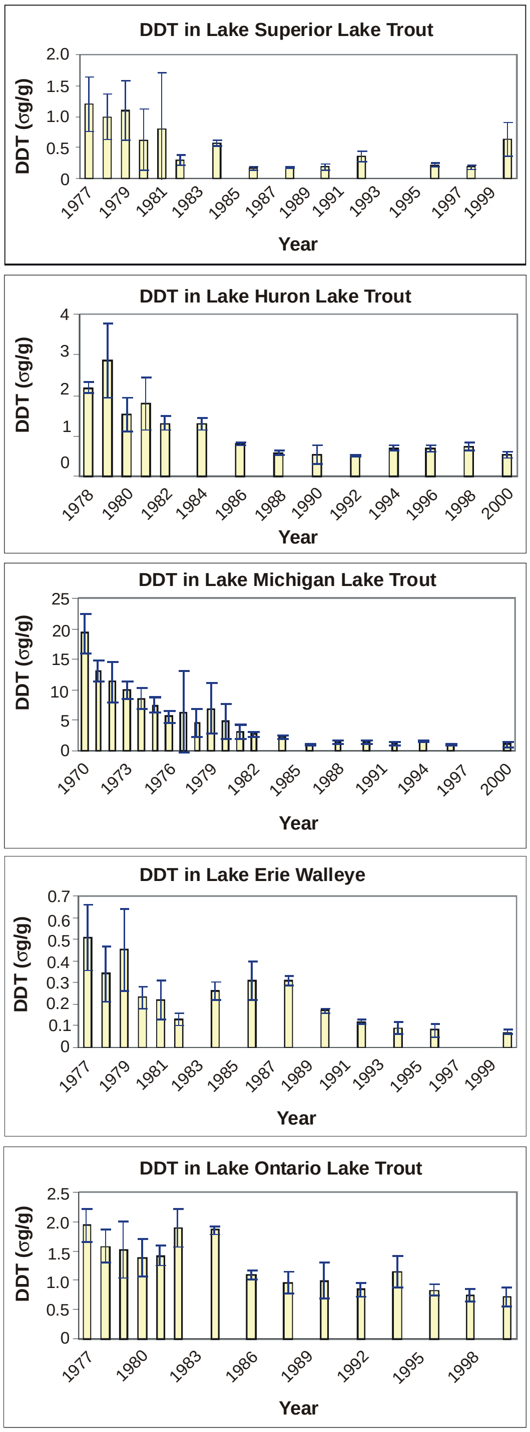

Figure 4. DDT found in whole Lake Trout, 1977-2001. µg/g wet weight +/- 95% C.I., composite samples, 600-700mm size range. Lake Erie data are for walleye in the 400-500mm size range. Note the different scales between lakes.

Source: U.S. Environmental Protection Agency

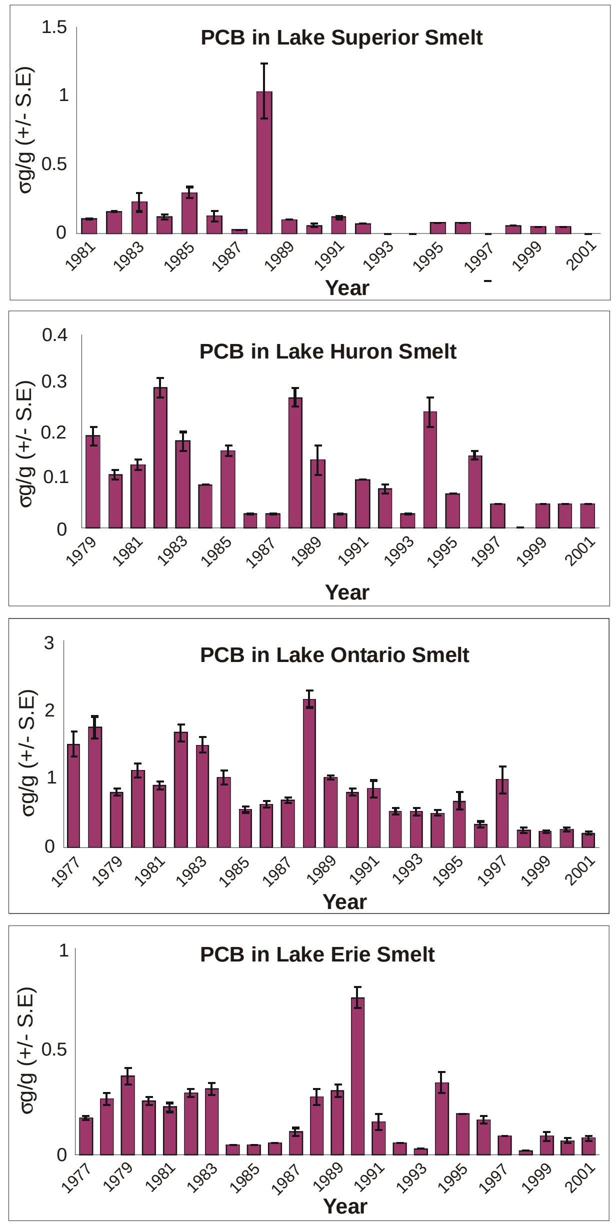

Figure 5. Total PCB levels in Great Lakes Rainbow Smelt, 1977-2001. Canadian data µg/g wet weight +/- S.E., whole fish. Note the different scales between lakes.

Source: Department of Fisheries and Oceans Canada

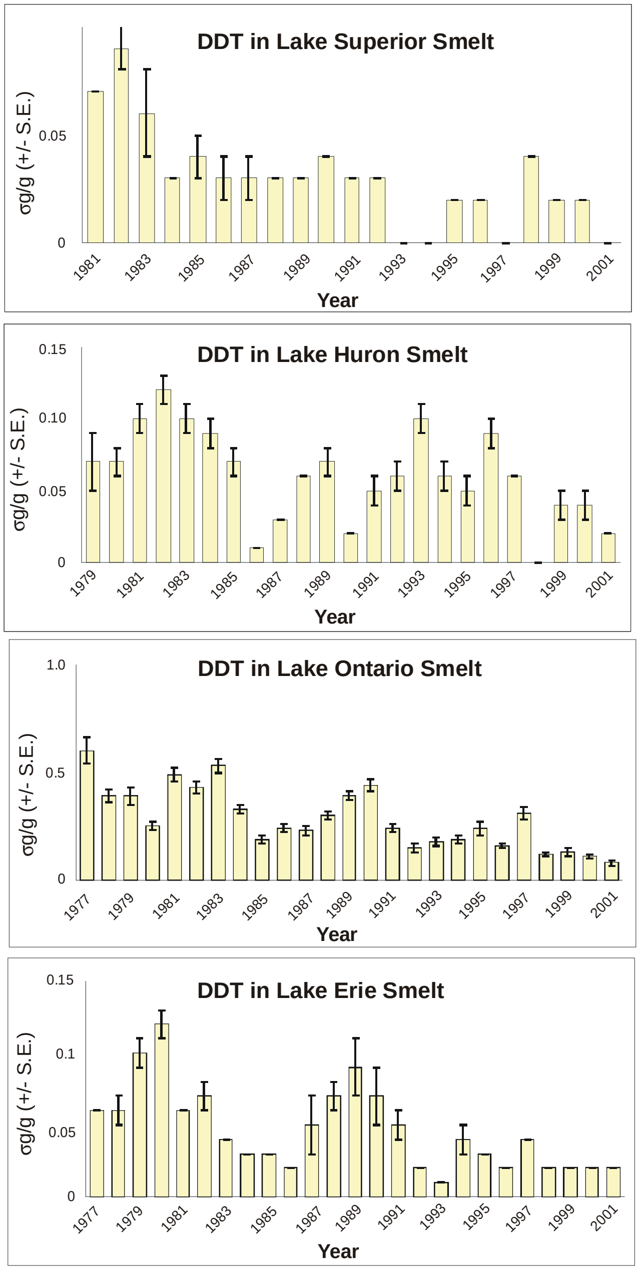

Figure 6. Total DDT levels in Great Lakes Rainbow Smelt, 1977-2001. Canadian data µg/g wet weight +/- S.E., whole fish. Note the different scales between lakes.

Source: Department of Fisheries and Oceans Canada

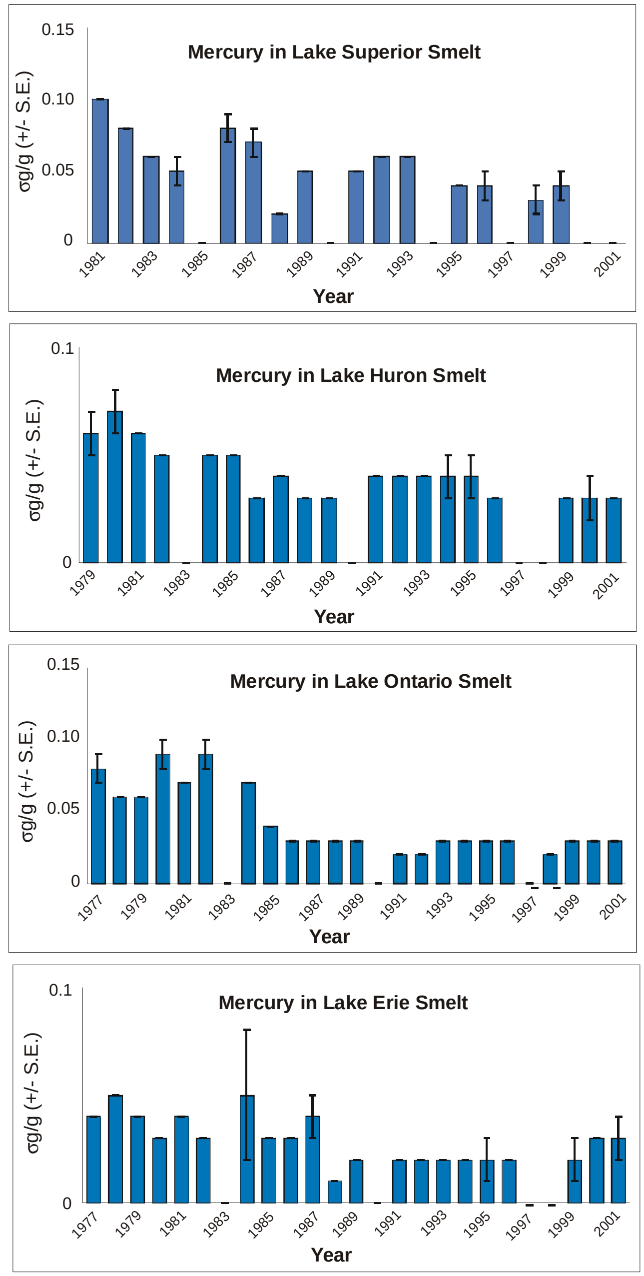

Figure 7. Total mercury levels in Great Lakes Rainbow Smelt, 1977-2001. Canadian data µg/g wet weight +/- S.E., whole fish. Note the different scales between lakes.

Source: Department of Fisheries and Oceans Canada

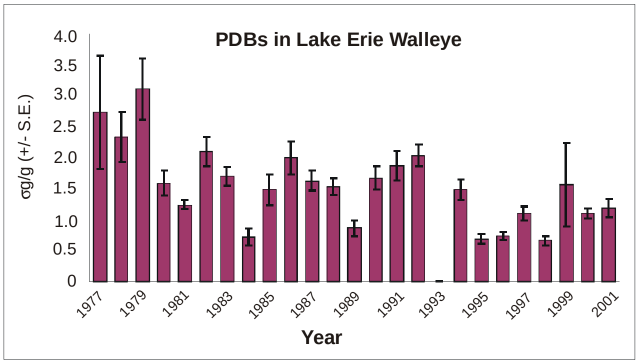

Figure 8. Total PCB levels in Lake Erie Walleye, 1977-2001. Canadian data µg/g wet weight +/- S.E., age 4+ - 6+ years.
Source: Department of Fisheries and Oceans Canada

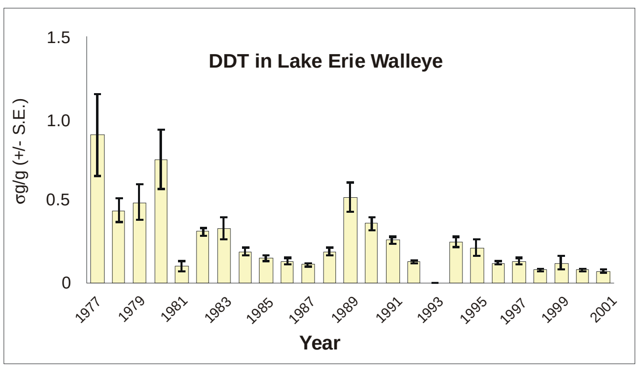

Figure 9. Total DDT levels in Lake Erie Walleye, 1977-2001. Canadian data µg/g wet weight +/- S.E., age 4+ - 6+ years.
Source: Department of Fisheries and Oceans Canada

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

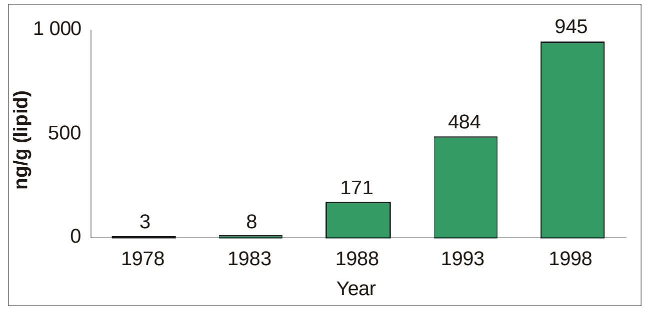

Figure 10. PBDE trends in Lake Ontario Lake Trout, 1978-1998. ng/g lipid weight +/- S.E., whole fish, age 6+ years.
Source: Department of Fisheries and Oceans Canada

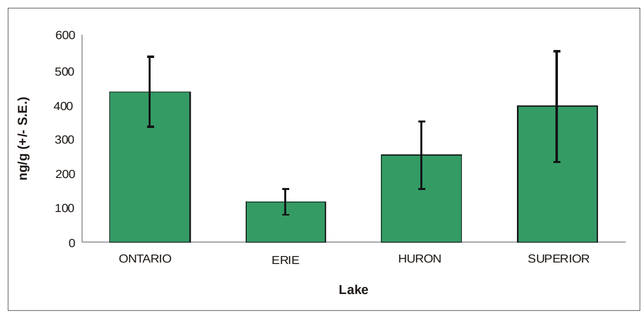

Figure 11. PBDE levels in Great Lakes Lake Trout, 1997. ng/g lipid weight +/- S.E., whole fish, age 6+ years.
Source: Department of Fisheries and Oceans Canada

in bioaccumulation patterns.

Most recently polybrominated diphenyl ethers (PBDEs) have been detected in Great Lakes fish at increasing concentrations (Luross, 2002) (Fig. 10). 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. 11), Lake Superior lake trout of the same age class, (6+), have the next highest concentration (DFO-unpublished data).

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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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.

Acknowledgments

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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 lip 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:

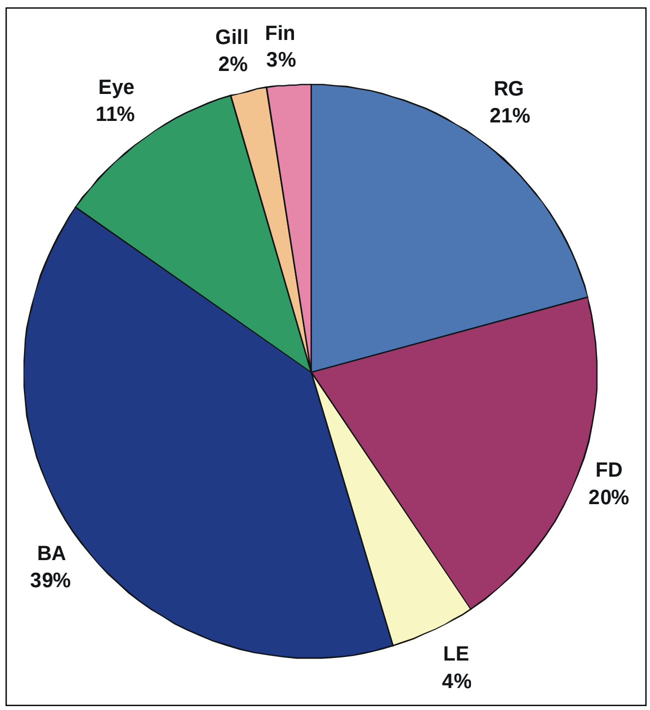

Figure 1. External anomalies on brown bullhead collected from Lake Erie from 1980s through 2000. BA – barbell abnormality, RG – raised growth (body and lip), FD – focal discoloration, LE – lesion (total 4439 fish).
Source:

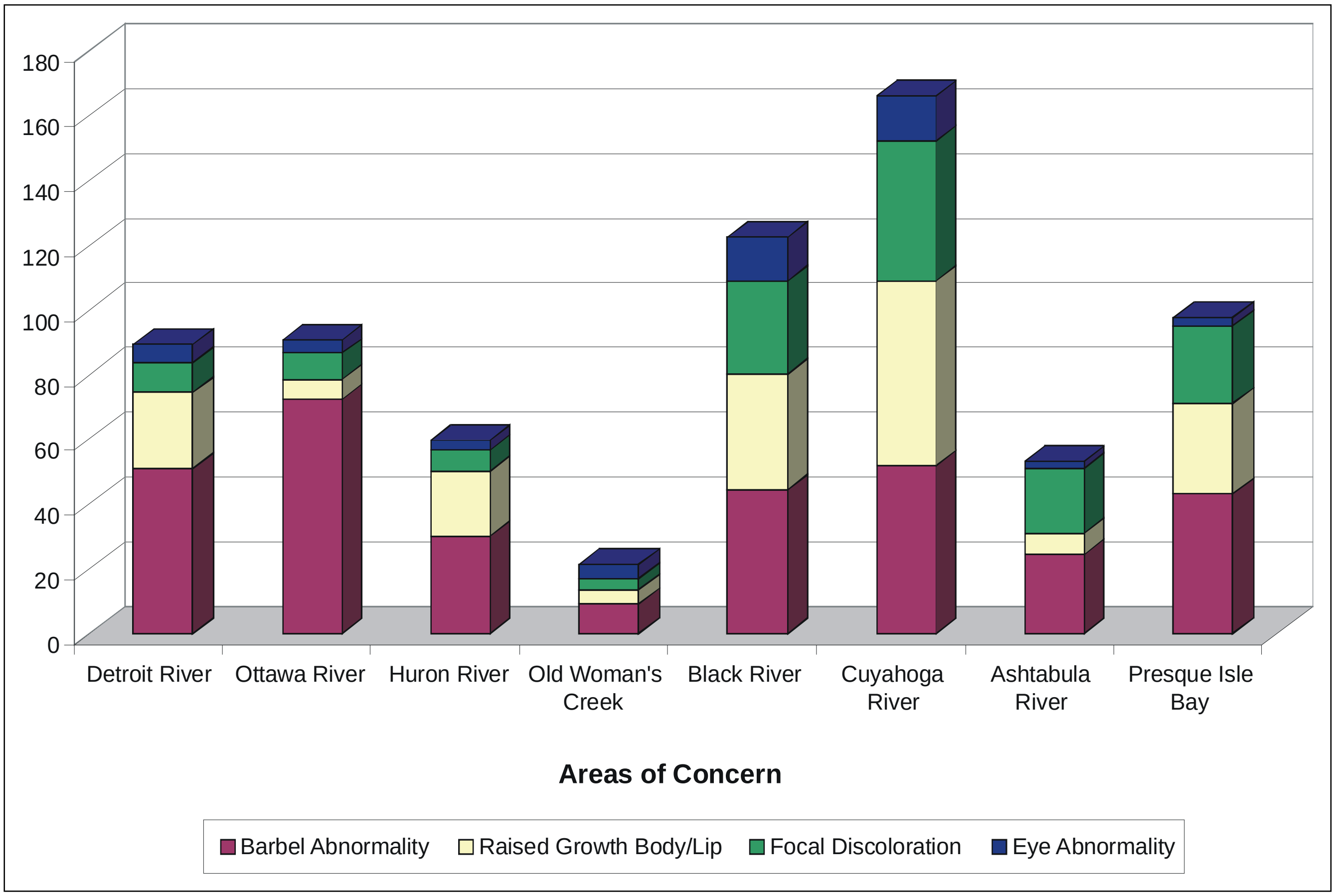

Figure 2. Prevalence of four most common external anomalies at Lake Erie areas of concern (AOCs). Huron River, OH and Old Woman's Creek, OH were used as reference sites.
Source:

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

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) from brown bullhead collected in 1998-2000.

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. Human 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 at Great Lakes AOCs 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).

Further 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.

Acknowledgments

Authors: Stephen B. Smith, U.S. Geological Survey, Biological Resources, Reston, VA and Paul C. Baumann, U.S. Geological Survey, Biological Resources, Columbus, OH.

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Section 3
Acknowledgments

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- Environmental Emergencies Section
- Meteorological Service of Canada
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- Great Lakes Science Center
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Commissions
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Environmental Non-Government Organizations
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Private Organizations
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