# SOLEC 2002

# Implementing Indicators
# Addendum

**DRAFT FOR DISCUSSION AT SOLEC 2002**

**OCTOBER 2002**

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Two indicators listed in the Implementing Indicators report were incorrectly categorized. Water Use (Indicator ID #7056) and Energy Consumption (Indicators ID #7057) indicators are to be categorized with the Societal suite of indicators, not the Land and Land Use indicators.

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**Biological Integrity - Douglas Dodge & Harvey Shear**

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## Salmon and Trout

Indicator ID #8

**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 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

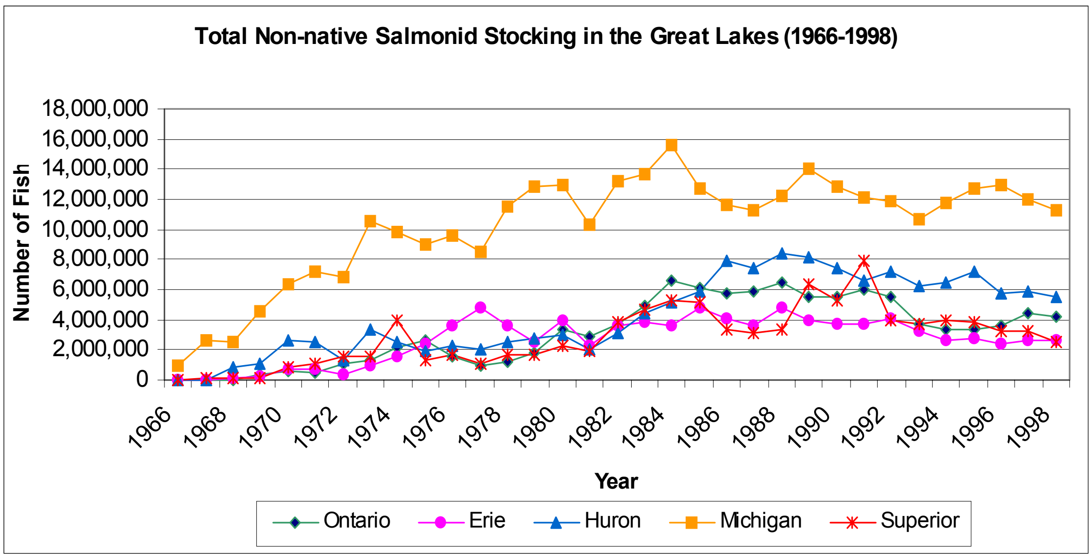


Figure 1. Total non-native salmonine stocking in the Great Lakes (1966-1998).

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).

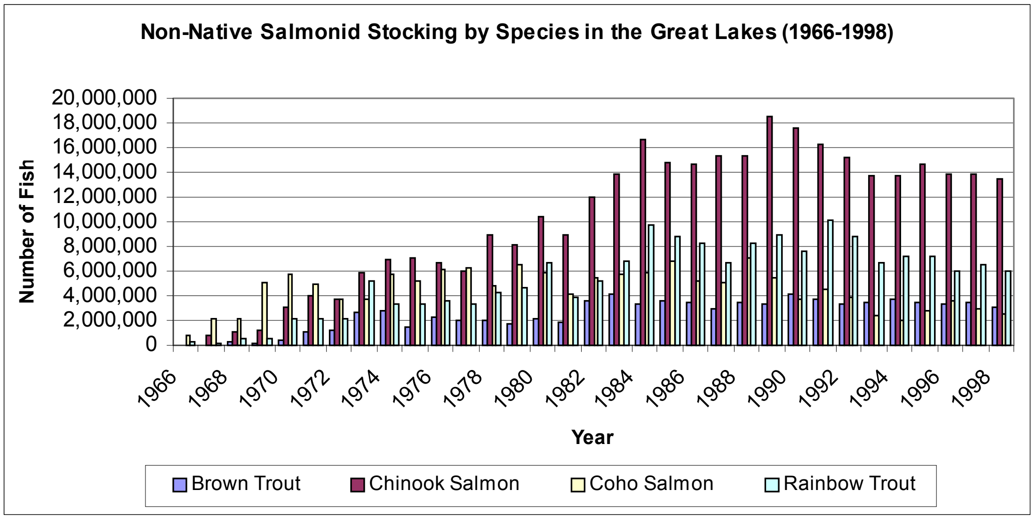


Figure 2. Non-native salmonine stocking by species in the Great Lakes (1966-1998). Source: Crawford (2001)

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**
Author: Melissa Greenwood, Environment Canada, Downsview, ON.
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. Also with the inclusion of other additional sources.

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**Preyfish Populations**
Indicator ID #17

**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 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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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.

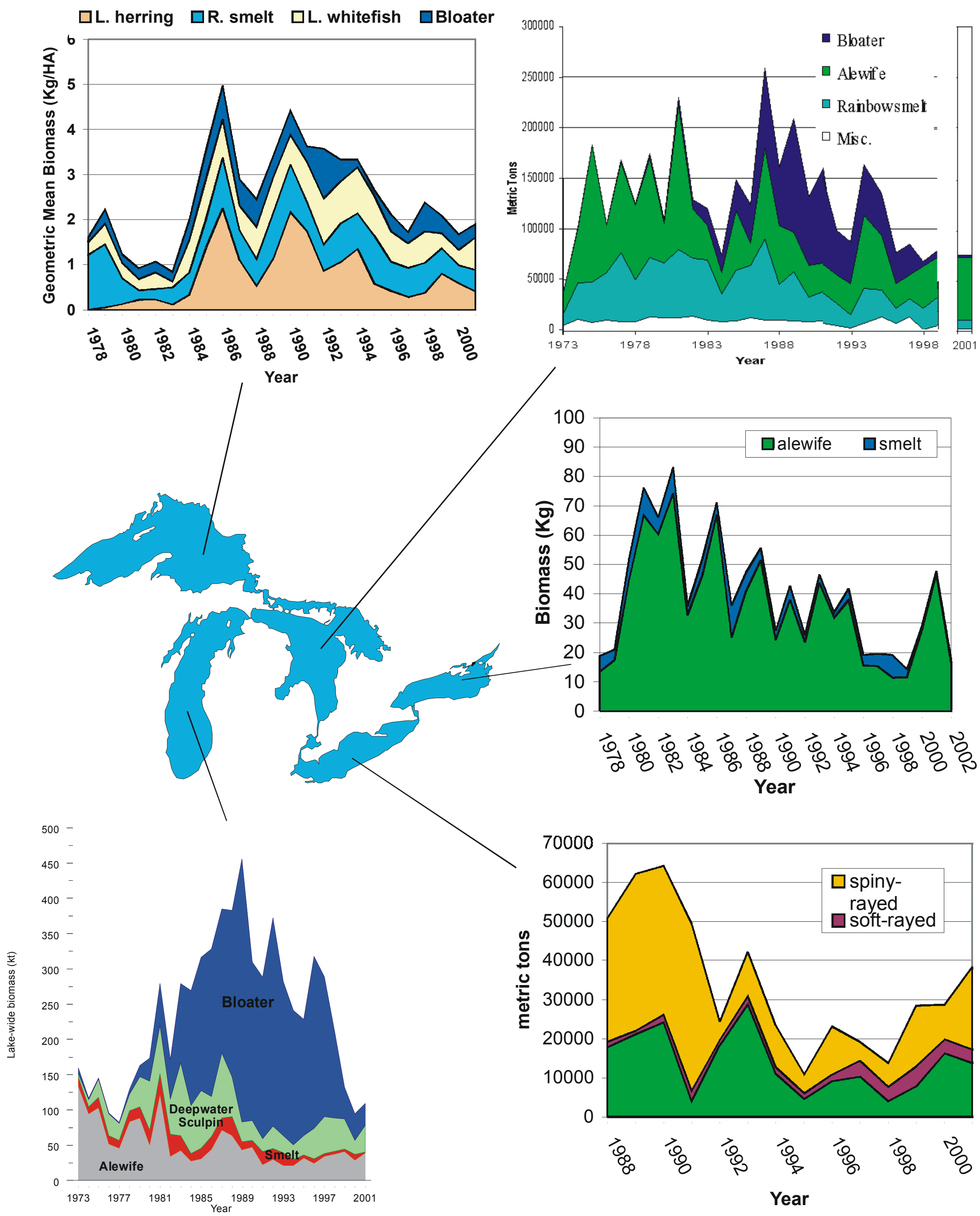


Figure 1. Preyfish population trends in the Great Lakes

## Sea Lamprey

Indicator ID #18

**Assessment:** Mixed Improving

**Purpose**

Estimates of the abundance of sea lampreys 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 native top predator, lake trout, and other fishes are negatively affected by mortality caused by sea lampreys.

**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*". 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 lampreys of varying specificity:

Superior (1990) - *50% reduction in parasitic-phase sea lamprey abundance by 2000, and a 90% reduction by 2010*;
Michigan (1995) - *Suppress the sea lamprey to allow the achievement of other fish-community objectives*;
Huron (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 (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 lampreys to less than 10% of their pre-control abundance all of the Great Lakes.

Mark and recapture estimates of the size of runs of sea lampreys 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 combined to estimate lake-wide abundance using a new regression model that relates run size to stream characteristics. 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 lampreys was met in 1994 and 1995, but abundance has increased since 1995. 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 where to continue. Abundance estimates for 2000 and 2001 show a pattern of decline. Stream treatments were increased during 2001 in response to the observed trends.

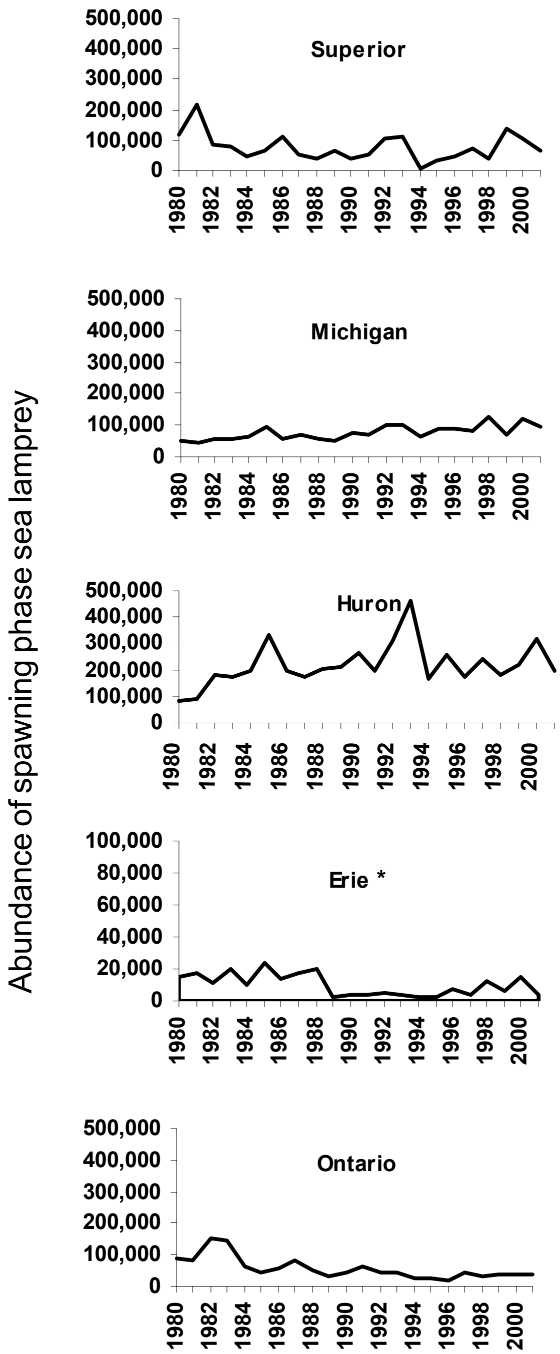


Figure 1. Total annual abundance of sea lamprey estimated during the spawning migration. Note the scale for Lake Erie is 1/5 larger than the other lakes.

*Lake Michigan:* Over the majority of the lake, populations have been relatively stable. Marking rates on lake trout have remained low for the period and the general FCOs are being met. However, a gradual increase in the lake population is continuing through 1999 and to the present. This continuing trend suggests sources of sea lampreys in Lake Michigan itself rather than from Lake Huron as previously believed. Stream treatments were increased in 2001 including treatment of previously untreated 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. During the early 1980s, populations increased in Lake Huron, particularly the north. This increase continued through to a peak in abundance during 1993. Through the 1990s Lake Huron contained more sea lamprey than all the other lakes combined. FCOs were not being achieved. The Lake 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 bottom-release lampricide, enhanced trapping of spawning animals, and sterile-male release was initiated in 1997. A decline in spawning-phase abundance is predicted for 2001 as a result of the completion of the first full round of lampricide spot treatments during 1999. While a decline was observed in 2001, the population shows considerable variation and the full effect of the control program will not be observed for another 2-4 years.

*Lake Erie:* Following the completion of the first full round of stream treatments in 1987, sea lamprey populations collapsed. Lake trout survival wounding rates declined and survival increased to levels sufficient to meet the rehabilitation objectives in the eastern basin. However lamprey abundance has increased since the early 1990's to levels that threaten the lake trout success. A major assessment effort during 1998 indicated that the source of this increase were several streams in which treatments had been deferred due to low water flows or concerns for non-target organisms. These critical streams have been treated during 1999 and 2000 and sea lamprey abundance is predicted to decline by 2002. The decline observed in 2001 might be a preliminary indication of success.

*Lake Ontario:* Abundance of spawning-phase sea lampreys has continued to decline to low levels through the 1990s. The abundance of sea lampreys has remained stable during 2000-2001. 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 lampreys 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 lampreys 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 lamprey predation or overfishing, there is evidence that the survival of parasitic sea lampreys increases 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 an 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 lampreys 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 lampreys need to continue. In addition, research to better understand lamprey/prey interactions, the population dynamics of lampreys that survive control actions, and refinement alternative methods are all key to maintaining sea lamprey at tolerable levels.

**Acknowledgments**

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## Contaminants in Young-of-the-Year Spottail Shiners

Indicator ID #114

**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.

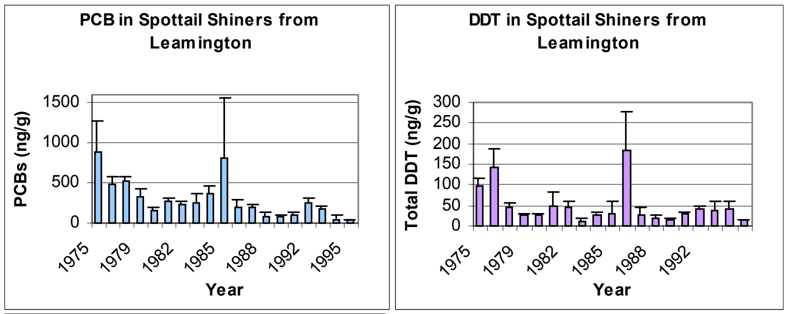
**State of the Ecosystem**

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 contaminants listed above are not frequently detected, and 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 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 were 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.



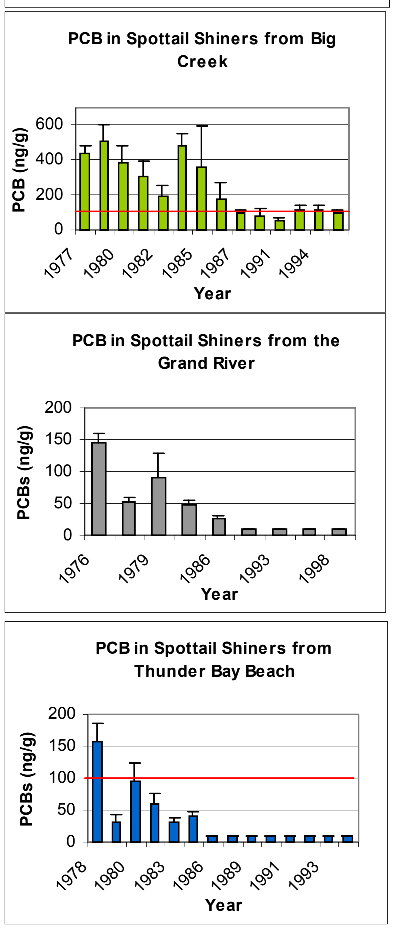




Figure 1. PCB and Total DDT Levels in Juvenile Spottail Shiners from Four Locations in Lake Erie. (The figures show mean concentrations plus standard deviations. The red line indicates the wildlife protection guideline. When not detected, one half of the detection limit was used to calculate the mean concentration.)

*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.

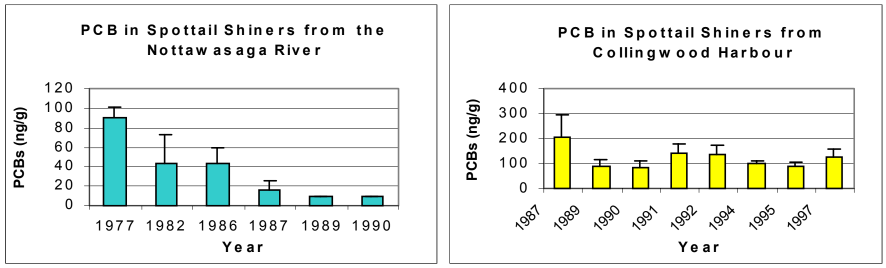



Figure 2. PCB Levels in Juvenile Spottail Shiners from Two Locations in Lake Huron. (The figures show mean concentrations plus standard deviations of PCBs. When not detected, one half of the detection limit was

*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 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).

*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 concentra-

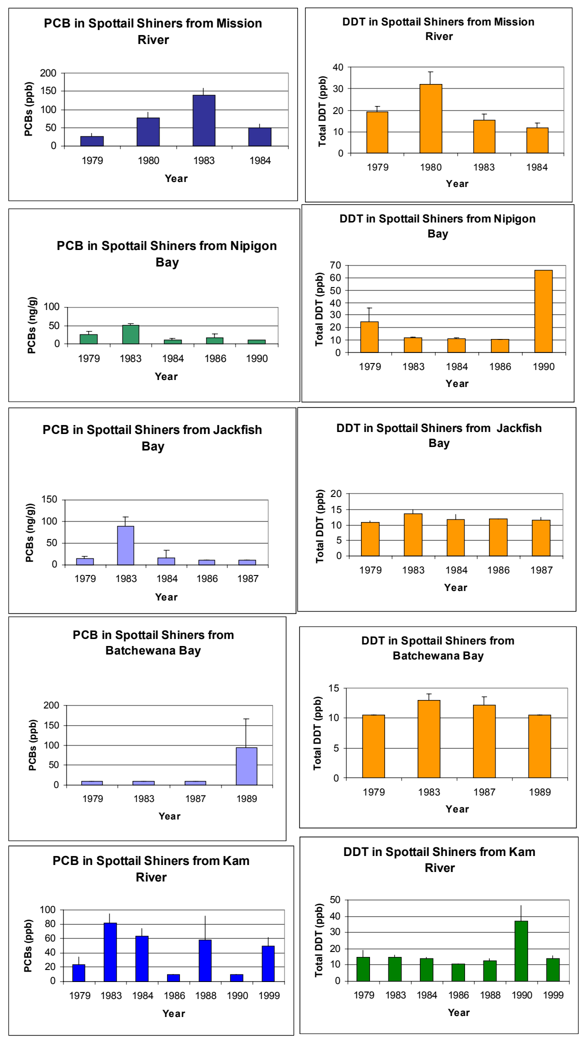
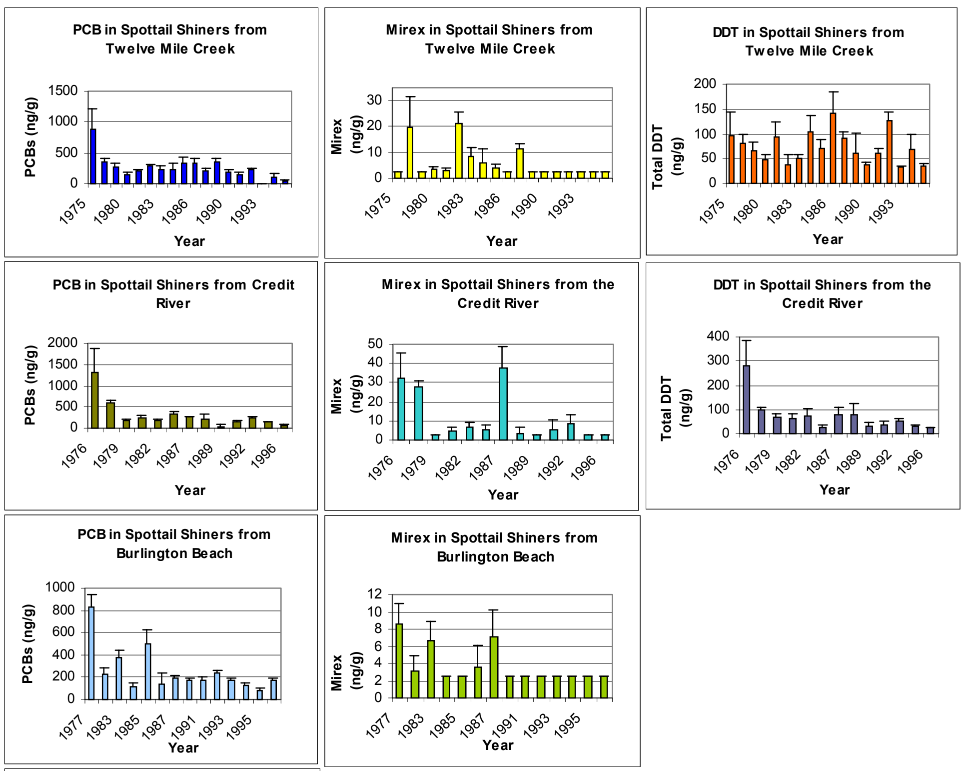



Figure 3. PCB and Total DDT Levels in Juvenile Spottail Shiners from Five Locations in Lake Superior. (The figures show mean concentra-

tions 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.



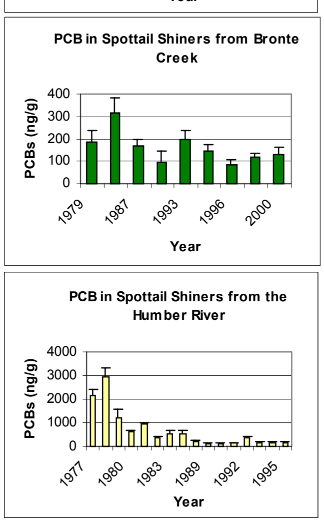




Figure 4. PCB, Mirex and Total DDT Levels in Juvenile Spottail Shiners from Five Locations in Lake Ontario. (The figures show mean concentrations plus standard deviations of PCBs, total DDT and mirex. When not detected, one half of the detection limit was

**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.

**Acknowledgments**

Author: Emily Awad and Alan Hayton, Sport Fish Contaminant Monitoring Program, Ontario Ministry of Environment, Etobicoke, ON.

Data: Sport Fish Contaminant Monitoring Program, Ontario Ministry of Environment.

**Sources**

Great Lakes Water Quality Agreement (GLWQA). 1978. Revised Great Lakes Water Quality Agreement of 1978. As amended by Protocol November 18, 1987. International Joint Commission, Windsor, Ontario.

Newell, A.J., D.W. Johnson and L.K. Allen. 1987. Niagara River Biota Contamination Project: Fish Flesh criteria for Piscivorous Wildlife. Technical Report 87-3. New York State Department of Environmental Conservation, Albany, New York.

Scheider, W.A., C. Cox, A. Hayton, G. Hitchin, A. Vaillancourt. 1998. 'Current Status and Temporal Trends in Concentrations of Persistent Toxic Substances in Sport Fish and Juvenile Forage Fish in the Canadian Waters of the Great Lakes'. *Environmental Monitoring and Assessment.* 53: 57-76.

Suns, K. and Rees, G. 1978. 'Organochlorine Contaminant Residues in Young-of-the-Year Spottail Shiners from Lakes Ontario, Erie, and St. Clair'. *J. Great Lakes Res*. 4: 230-233.

## Brownfields Redevelopment

Indicator ID #7006

**Assessment:** Mixed Improving

**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 granted to voluntary remediated programs or state brownfields cleanup programs, while some track the number of sites that have been redeveloped. The overall number of sites being addressed reflects the level of cleanup activity or amount of financial support from each state, but does not necessary reflect land renewal efforts (i.e., acres of land redeveloped). Furthermore, states and provincial cleanup figures do not necessarily reflect local brownfields remediation efforts and may include revitalization of underutilized sites that are not considered brownfields. Where cleanups do not have formal reporting requirements, there is no information base for tracking brownfield cleanups or redevelopment. No Great Lakes state or province tracks acres of brownfields *redeveloped*, though several are beginning to track acres of brownfields *remediated*.

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 reuses 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. To address to brownfields reuse, 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.

Information on acres of brownfields remediated from Illinois, Minnesota, New York, Ohio, Pennsylvania and Quebec indicate that a total of 33,389 acres have been remediated in these states and provinces alone, and approximately 4,600 acres have been remediated between 2000-2002. Available data from eight Great Lakes states and Quebec indicates that more than 16,714 brownfields sites have participated in brownfields cleanup programs. Redevelopment is a criteria 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 redevelopment, 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**

Poor land use planning and a market economy that encourages new development to occur on undeveloped land over urban brownfields is a significant and ongoing pressure that can be expected to continue.

Programs to monitor and enforce of exposure controls are in their infancy. The lack of a means of tracking and verifying the effectiveness of exposure controls present an ongoing pressure.

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 many continue to be at risk from brownfields contamination even where brownfields have been pronounced "clean".

**Future Activities**

Programs to monitor and enforce 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 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.

**Future 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, consistency in data gathering also 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) geographic location; 4) level of urbanization; and 5) type of reuse (i.e., commercial, residential, open, none, etc).

**Acknowledgment**
Author: Victor Pebbles and Kevin Yam, Great Lakes Commission, Ann Arbor, MI.
Sources: personal communication with Great Lakes State Brownfield/Voluntary Cleanup Program Managers.

## Green Planning Process
Indicator ID #7053

**Assessment:**

**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 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). 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 has been challenging. (2) Most successful reforms have had a governor or legislator as a political champion. (3) Linking reforms to quality-of-life issues has been key. (4) Coalitions and consensus have promoted planning reforms. (5) Reforms have sometimes lead to backlash. (6) Task forces are often the starting point for planning reforms. (7) Some areas, particularly in the West, have used ballot initiatives to initiate reforms. (8) Piecemeal reforms are politically more popular than comprehensive ones. While recognizing the hidden costs of unmanaged growth has spurred the revision of outdated planning and zoning laws, funding for implementation remains a problem.

The following are some examples of data obtained from municipalities in parts of the U.S. Great Lakes Basin for this project. Summary data and graphs for larger portions of the Basin will be added to this indicator report after it is analyzed. 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 but 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.

In the rural western Upper Peninsula (U.P.) of Michigan, the Western U.P. Planning and Development Regional Commission recently surveyed the 72 local units of government in its 6-county region regarding basic planning and zoning information. Of the 64 municipalities that responded, only 29 have planning commissions, 20 have land use or comprehensive plans, and 44 have zoning (49 counting the townships covered by the Keweenaw County ordinance).

**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 much lip service, too little a priori 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 and 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. State governments are enacting laws and developing programs in these areas, as well. 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 and boards and sometimes with links 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. A revised report will be available in November 2002. 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**

Author: 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.

**Sources**

The following websites contain useful information on planning and "smart growth": American Planning Association (http://www.planning.org/growingsmart/states2002.htm and http://www.planning.org/growingsmart/states.htm); Western New York Regional Information Network of the University at Buffalo (State University of New York, http://rin.buffalo.edu/s_envi/envi.html). Nathan Zieziula of the Crawford County (Pennsylvania) Planing 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. 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 within the county. Mary Taddeucci provided information for the 6-counties served by the Western Upper Peninsula Planning and Development Regional Commission in Michigan.

## Contaminants in Edible Fish Tissue

Indicator ID # 4083

**Assessment:** Mixed Improving

### Purpose

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."

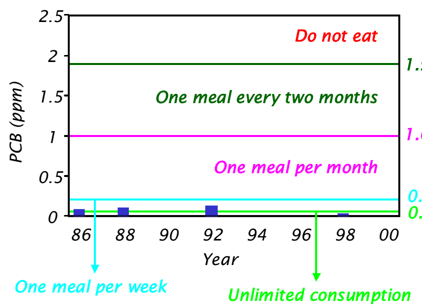
### State of the Ecosystem

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.

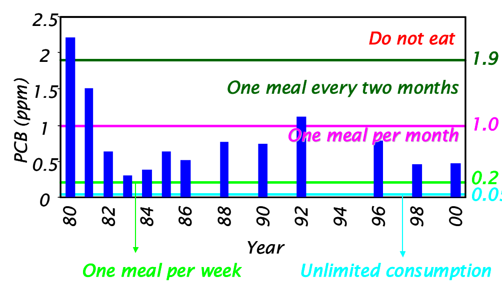
Fish Consumption Programs are well established in the Great Lakes. States, tribes, and the province of Ontario have extensive fish contaminant monitoring programs and issue advice to their residents about how much fish and which fish are safe to eat. This advice ranges from recommendations to not eat 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. 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 |
|---|---|
| Superior | PCBs, mercury, toxaphene, chlordane, dioxin |
| Huron | PCBs, mercury, dioxin, chlordane |
| Michigan | PCBs, mercury, chlordane, dioxin |
| Erie | PCBs, dioxin |
| Ontario | PCBs, mercury, mirex |

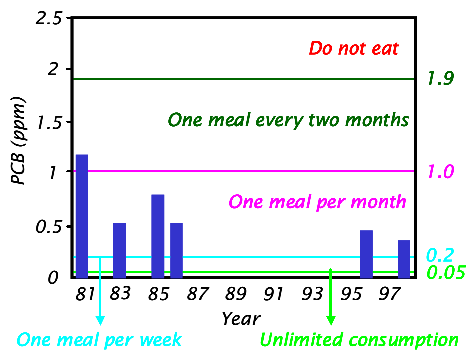
PCBs in Lake Superior Coho Salmon



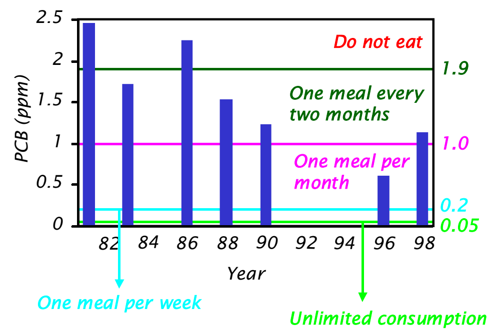

PCBs in Lake Michigan Coho Salmon



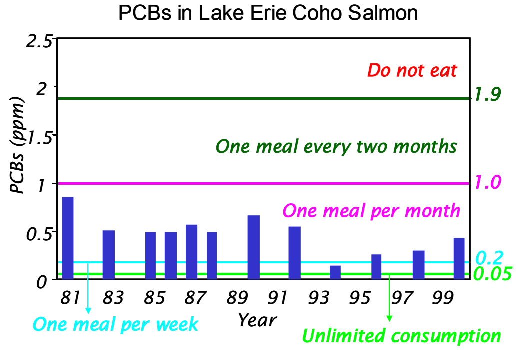

PCBs in Lake Huron Coho Salmon




PCBs in Lake Ontario Coho Salmon




PCBs in Lake Erie Coho Salmon




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 fish 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 sometimes different for the same lake and species 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 fish. Emerging contaminants, such as certain brominated flame retardants, are increasing in the environment and causing concern.

Screening studies on a larger suite of chemicals 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 carry out 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 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.

**Acknowledgments**

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

**Figure xx.** Historical levels of PCBs in salmon from the Great Lakes shown with corresponding meal advice per the "Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory" (Blank indicates No Sampling).

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

## Solid Waste Generation

Indicator ID #7060

**Assessment:** Mixed

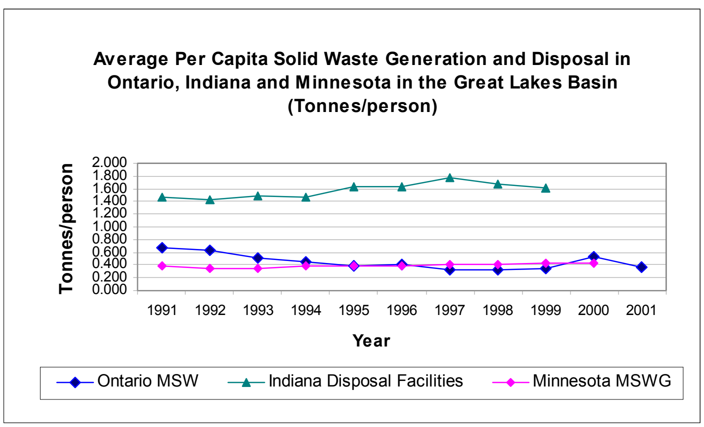
**Purpose**

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.** Average Per Capita Solid Waste Generation and Disposal from a selection of municipalities in the Ontario, Indiana and Minnesota portion of the Great Lakes basin (1991-2001).
Source: IDEM – Indiana Department of Environmental Management. 2000 Summary of Indiana Solid Waste Facility Data Report. MOEA - Minnesota Office of Environmental Assistance. Report on 2000 SCORE Programs report.

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 4 % decrease of the amount disposed.

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.

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 2%. The amount of GSW increased 3% for NWDO over the same time period. The recycled amount increased 5% for NEWO and 17% for NWDO from 1999 to 2000.

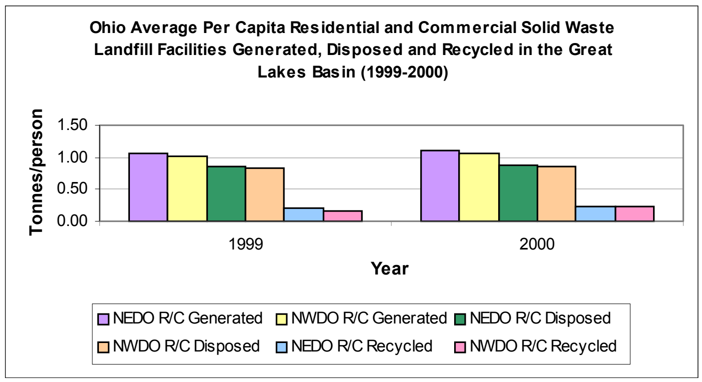



Figure 2. Ohio Counties Average Per Capita Solid Waste Landfill facilities Generated, Disposed and Recycled in the Great Lakes Basin (1999-2000).
Source: Ohio Environmental Protection Agency, Division of Solid and Infectious Waste Management.

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.

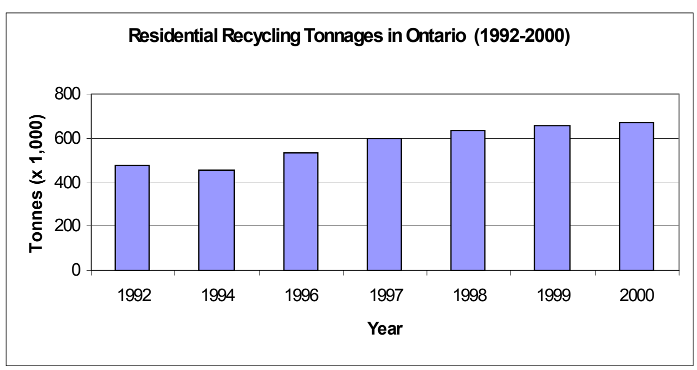



**Figure 3.** Residential Recycling Tonnages in Ontario (1992-2000). Source: WDO – Ontario Waste Diversion Organization (2001c). Municipal 3Rs in Ontario: 2000 Fact Sheet.

**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 year to dispose of such wastes and existing landfills 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**

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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 there websites. Environmental Protection Agency Region 5 in Chicago, 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)

Michigan data of the total solid waste disposed in Michigan Landfills per capita in cubic yards for 1996-2001, was provided by Michigan Department of Environmental Quality,

Waste Management Division. The report was used and adapted to calculate the per capita amount using the census-estimated population 1996-2001. (http://www.deq.state.mi.us)

Minnesota data of the Municipal solid waste generation per capita for 1991-2000, was provided by Minnesota Office of Environmental Assistance (MOEA). The SCORE report is a full report to the Legislature that the main components is to identify and targeting source reduction, recycling, waste management and waste generation collected from all 87 counties in Minnesota. (http://www.moea.state.mn.us)

New York data of the Solid waste generated and recycled in tones for 1990-1998, was provided by New York State Department of Environmental Conservation, Division of Solid and Hazardous Materials. The data was adapted to obtain the per capita generation with the census-estimate population per year. (http://www.dec.state.ny.us)

Ohio data of Disposed and recycled generated solid waste per capita in landfills for each solid waste management district for 1999-2000, was provided by Ohio Environmental Protection Agency, Division of Solid Waste and Infectious Waste Management. The data of Northeast and Northwest district office was adapted by counties on the Great Lakes basins and census-estimate data population per year. (http://www.epa.state.oh.us)

Pennsylvania data of the Average per capita recycled generation rates was provided by Pennsylvania Department of Environmental Protection, Bureau of Land Recycling and Waste Management. (http://www.dep.state.pa.us)

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)