Appendix 1 — Descriptor Information for Indicators in the SOLEC

Indicator Suite

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

Nearshore and Open Water Indicators

Coastal Wetland Indicators

Nearshore Terrestrial Indicators

Land Use Indicators

Human Health Indicators

Societal Indicators

Unbounded Indicators

Fish Habitat (Indicator ID: 6)

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

Purpose
This indicator will assess the quality and amount of aquatic habitat in the Great Lakes ecosystem, and it will be used to infer progress in rehabilitating degraded habitat and associated aquatic communities.

Ecosystem Objective
This indicator addresses the general Fish Community Goals and Objectives (FCGO) to protect and enhance fish habitat, achieve no net loss of the productive capacity of habitat supporting fish communities, and restore damaged habitats. Annex 2 of the GLWQA calls for the restoration of lost or damaged habitat. The indicator also supports the policy position of the Great Lakes Fishery Commission (GLFC), Habitat Advisory Board, presented in their 1998 Draft Binational Policy and Action Plan for the Protection and Enhancement of Aquatic Habitat in the Great Lakes.

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

Features
This indicator will measure/calculate changes in aquatic habitat by area, by type, by location, by Lake, and by Biodiversity Investment Areas. Significant losses and degradation of aquatic habitat have occurred in the Great Lakes aquatic ecosystem since the late 1800s when European settlement of the region was completed. Logging, navigation projects, dam construction, shoreline development, agriculture, urbanization, municipal and industrial waste disposal, and water withdrawal by power generation facilities for once-through cooling have all acted to reduce the amount and quality of aquatic habitat in the system. These affected habitats include the Great Lakes proper, their connecting channels and coastal wetlands, and the tributaries that provide linkages with inland aquatic habitats and terrestrial habitats via the surface water continuum.

Wetland losses in the region have been reasonably well documented and quantified, but losses of the other major habitat types have not. Recent efforts to relicense hydropower dams in the United States have led to a reconsideration of the habitat losses associated with these dams and a useful picture is emerging which allows an assessment of the adverse impacts of habitat fragmentation on anadromous and resident stream-fish communities. Data for tributary habitat are being developed in connection with FERC dam relicensing procedures in the United States. Data are presently available for Michigan, New York State, and Wisconsin.

Large volumes of water are withdrawn from the Great Lakes and their connecting channels for use by industry and municipalities. Steam-electric power plants using once-through cooling, and pumped-storage hydropower plants withdraw the greatest volumes of water. Fish of all sizes are entrained with this water and substantial mortality occurs basin-wide among the entrained population. Rates of water withdrawal and associated fish mortality rates are known for existing steam-electric power plants using once-through cooling and for pumped-storage hydropower plants. Reduction in water withdrawal rates or the addition of effective screening devices at existing facilities would reflect an improvement in fish habitat, and hence a reduction in fish entrainment mortality.

Illustration

Limitations
Restoration ecology is an emerging scientific discipline requiring an understanding of multiple disciplines and partnerships. Comprehensive, detailed habitat inventory, classification, and mapping of Great Lakes aquatic habitats has not been undertaken. Much more research will be required to recognize critical fish habitat and to understand the relationship between quantity of habitat and aquatic production. Interpretation of habitat measurements is confounded by issues such as interacting species and connectivity of habitat between life stages.

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

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

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

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

Relevancies
Indicator Type: state
Environmental Compartment(s): water, fish
Related Issue(s): habitat
SOLEC Grouping(s): **open waters**, **nearshore waters**, coastal wetlands
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 25, 2000

Salmon and Trout **(Indicator ID: 8)**

Measure
1) Productivity, yield, or harvest of Pacific salmon, rainbow trout and brown trout using abundance (e.g., catch of each species in a given unit of sampling effort), or biomass metrics; and 2) populations of these stocked and naturally produced fish.

Purpose
This indicator will show trends in populations of introduced trout and salmon populations, and it will be used to evaluate the potential impacts on native trout and salmon populations and the preyfish populations that support them.

Ecosystem Objective
"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."[1]
In addition, this indicator supports Annex 2 of the GLWQA.

Endpoint
The current Fish Community Goals and Objectives (FCGO) for introduced trout and salmon species establish harvest or yield targets consistent with FCGO for lake trout restoration, and in Lake Ontario, for Atlantic salmon restoration. The following index targets for introduced trout and salmon species were provided in the FCGO for the listed lake.
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 salmonids.*
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 salmonid predators, while maintaing a predator/prey balance which allows normal growth of lake trout.*

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

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

Illustration

Limitations
The data for this indicator are collected annually by the states for certain segments of the fishery (e.g., Michigan's segment of the Lake Michigan charter boat fishery) and are available for reporting, but there is no coordinated, basin-wide data collection program. Reporting occurs as news releases and as reports to the Lake Committees of the Great Lakes Fishery Commission. More analysis of existing data and evaluation of management alternatives through mathematical modelling is needed before more detailed species-by-species harvest can be defined.

Interpretation

Comments
[1] Great Lakes Fishery Commission. 1997. A Joint Strategic Plan for Management of Great Lakes Fisheries, Ann Arbor, Mi.

Pacific salmon and Rainbow and Brown trout are introduced species. Some of these are now naturalized but stocking still occurs. Atlantic salmon, which were native to Lake Ontario, have been introduced at times to the other four Great Lakes. Atlantic salmon introductions to the upper four Great Lakes should be treated as potentially beneficial range extensions of the species within the basin. This valuable species is in decline in most of its historical Western Atlantic range, and the establishment of naturalized populations in the Great Lakes would help ensure the survival of the Western Atlantic gene pool.
The salmonine community will consist of both wild and planted salmonines and exhibit increasing growth of, and reliance on, natural reproduction. Short-term restrictions of harvest may be required to achieve long-term goals of natural reproduction.

Manipulation of the mix of salmonines should, in theory, result in higher catches than those produced solely by lake trout. The lake trout historically inhabited the whole water column, but its use of the pelagic food web (although substantial) could not have been as efficient as the contemporary species mix of lake trout and of pelagic piscivores--Pacific salmon, brown trout, and rainbow trout.

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

Fin clips were used in past to mark introduced fish. Coded wire tags are used mostly on fingerlings, currently. Several other marking techniques are used less frequently. Otolith, scale, and fin ray abnormalities used for fish smaller at release and for F2 and later recoveries.

Unfinished Business

< There needs to be more information on the spatial and temporal trends this indicator will describe, as well as potential variability in the data.

< The method of graphically displaying this indicator needs to be determined. For example, will bar graphs or maps be used to depict trends over time? What will appear on the graphs or maps?

< There needs to be more information added to help better understand the trends presented by this indicator.

Relevancies

Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens, nutrients, exotics, habitat
SOLEC Grouping(s): **open waters**, **nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s): Ontario, Huron, Michigan, Superior
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

Last Revised

March 7, 2000

Walleye and Hexagenia (Indicator ID: 9)

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

Purpose
This indicator will show the status and trends in walleye and Hexagenia populations, and it will be used to infer the basic structure of warm-coolwater predator and prey communities, the health of percid populations, and the health of the Great Lakes ecosystem.

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

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

Lake Huron (1995): *Reestablish and/or maintain walleye . . . with populations capable of sustaining a harvest of 0.7 million kg*
Lake Michigan (1995): *Expected annual yield: 0.1-0.2 million kg*
Lake Erie (1999): *Manage the western, central and eastern basin ecosystems to provide sustainable harvests of valued fish species, including walleye . . .*
No reference values available for Lakes Superior and Ontario.

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

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

Illustration

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

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

Probable causative agents of impairment for Hexagenia include excess nutrients and pollution of surficial sediments with metals and oil.

Comments

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

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

Unfinished Business

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

Relevancies

Indicator Type: state
Environmental Compartment(s): biota, fish
Related Issue(s): contaminants & pathogens, nutrients, exotics, habitat
SOLEC Grouping(s): **open waters**, **nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s): Ontario, Erie, Huron
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 6: Degradation of benthos

Last Revised

March 7, 2000

Preyfish Populations (Indicator ID: 17)

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

Purpose
This indicator will assess the abundance and diversity of preyfish populations, and it will be used to infer the stability of predator species necessary to maintain the biological integrity of each lake.

Ecosystem Objective
To maintain a diverse array of preyfish populations to support healthy, productive populations of predator fishes as stated in the FCGOs for each lake. For Lake Michigan, the Planktivore Objective (GLFC, 1995) states: Maintain a diversity of prey (planktivore) species at population levels matched to primary production and to predator demands. This indicator also relates to the 1997 Strategic Great Lakes Fisheries Management Plan Common Goal Statement for Great Lakes Fisheries Agencies and to Annex 2 of the GLWQA.

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

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

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

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

Interpretation

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

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

Relevancies
Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens, nutrients, exotics, habitat
SOLEC Grouping(s): **open waters**, **nearshore waters**

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

Last Revised
March 8, 2000

Sea Lamprey (Indicator ID: 18)

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

Purpose
This indicator will estimate sea lamprey abundance and assess their impact on other fish populations in the Great Lakes.

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

The 1955 Convention of Great Lakes Fisheries created the Great Lakes Fishery Commission “to formulate and implement a comprehensive program for the purpose of eradicating or minimizing the sea lamprey populations in the Convention area.”

In addition, this indicator supports Annex 2 of the GLWQA.

Endpoint
This indicator will refer to the index target abundances for sea lamprey populations provided in the most current Fish Community Goals and Objectives (FCGO) for each lake. The following objectives are listed in the FCGO with the date of issue for each lake.
Lake Huron (1995): *75 % reduction by 2000; 90 % reduction by 2010.*
Lake Ontario (1999): *Suppression of sea lamprey populations to early-1990s levels, and maintaining sea lamprey marking rates <0.02 marks per fish for lake trout.*
Lake Michigan (1995): *Suppress the sea lamprey to allow the achievement of other fish-community objectives.*
Lake Erie (1999 draft): *Unspecified Objective.*
Lake Superior (1990): *50 % reduction in parasitic-phase sea lamprey abundance by 2000; 90 % reduction in parasitic-phase sea lamprey abundance by 2010.*

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

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

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

Wounding rates may be influenced by the abundance of prey in the suitable size range and may vary among major prey species depending on the mix of these fishes in an area. The season of data collection (e.g., spring or fall) affects the interpretation of the measure and must be kept constant. Classification of sea lamprey wounds (i.e., wounds or scars, Type A or Type B) is subjective and may vary among individuals and agencies making the observation. The GLFC and cooperating biologists attempt to standardize evaluations as much as possible through workshops and other opportunities to share information.

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

Comments

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

Unfinished Business

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

Relevancies

Indicator Type: pressure
Environmental Compartment(s): fish
Related Issue(s): exotics
SOLEC Grouping(s): **open waters**, **nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

Last Revised

March 7, 2000

Native Unionid Mussels (Indicator ID: 68)

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

Purpose
This indicator will assess the population status of native Unionid populations, and it will be used to infer the impact of the invading Dreissenid mussel on the Unionid mussel.

Ecosystem Objective
The diversity of native invertebrate fauna should be maintained in order to stabilize ecosystem habitats throughout the Great Lakes and their tributaries and connecting channels. In addition, this indicator supports Annex 2 of the GLWQA.

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

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

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

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

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

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

Comments
The first step is to document where Unionids are located and what species are present. The second step is to determine if young Unionids of any species are present at a site. Secondary sampling efforts can focus on species of concern. The number of Unionid species at a given site in the Great Lakes basin varied widely. Most Unionid communities historically supported >12

species, depending on locality. Lake Huron probably never had more than 6-7 species, but Lake Erie and the connecting channels had 16-18, and the Unionid communities in inland waters in Michigan typically had about 16 species.

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

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

Unfinished Business

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

Relevancies

Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): exotics
SOLEC Grouping(s): **open waters**, **nearshore waters**, coastal wetlands
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s):
Beneficial Use Impairment(s): 6: Degradation of benthos

Last Revised

March 8 , 2000

Lake Trout and Scud (*Diporeia hoyi*) (Indicator ID: 93)

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

Purpose
This indicator will show the status and trends in lake trout and scud populations, and it will be used to infer the basic structure of coldwater predator and prey communities and the general health of the ecosystem.

Ecosystem Objective
"Lake Superior should be maintained as a balanced and stable oligotrophic ecosystem with lake trout as the top aquatic predator of a coldwater community and the [*Diporeia*] hoyi as a key organism in the food chain" (GLWQA). Lake trout are also historically important top predators in the other Great Lakes and should be maintained in accordance with the lake-specific Fish Community Goals and Objectives. Relates to Annexes 1 and 2 of the GLWQA.

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

Self-sustainability and appropriate lake-specific quantitative measures of abundance, yield, or biomass should be established as reference values in the other lakes. The reference values can perhaps be based on target values provided in the FCGO for each lake:
Lake Superior (1990): *Achieve a sustained annual yield of 4 million pounds of lake trout from naturally reproducing stocks. . .*
Lake Huron (1995): *Establish a diverse salmonine community that can sustain an annual harvest of 2.4 million kg with lake trout the dominant species. . .*
Lake Michigan (1995): *Establish 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. Establish self-sustaining lake trout populations.*
Lake Erie (1999 draft): *Manage the eastern basin ecosystem to provide sustainable harvests of valued fish species, including . . . lake trout. . . Continue efforts to restore a self-sustaining population of lake trout to the modest levels of abundance observed historically. . .*
Lake Ontario (1999): *Achievement of rehabilitation measures for lake trout (Schneider et al. 1998).*

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

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

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

Limitations
The indicator is of greatest value in assessing ecosystem health in the oligotrophic, open-water portions of Lake Superior; it may be less useful in nearshore areas of the lake and the quantitative reference values for Lake Superior may not apply closely to oligotrophic areas of the other lakes. Target reference values for scud abundance have not been developed for all five lakes. Because the indicator includes only two species, it may not reliably diagnose causes of degraded ecosystem health. A number of lakewide surveys and assessments of benthic invertebrates communities, including scud, have been made over the past several decades in the Great Lakes. The current status of scud populations is generally known, and an understanding of the changes related to the Dreissenid mussel invasion is emerging.

Interpretation
Interpretation is direct and simple. If the target values are met, the system can be assumed to be healthy; if the values are not met there is health impairment. However, the availability, or lack thereof, of appropriate lake trout strains may contribute to difficulties encountered in attempts to rehabilitate lake trout and further complicates the interpretation of "healthy" ecosystem function. Causative agents of impairment are not addressed by the indicator.

Comments
Most stocked lake trout are tagged or marked so that the performance of different strains being tested can be evaluated. Unmarked lake trout that are captured are examined in various ways to determine if they were produced by natural spawning. When the number of naturally spawned fish in the lake is judged to be sufficient to meet abundance or production or yield goals outlined above or in Fish Community Goals and Objectives (FCGO) for lake trout, the population in the lake is judged to be self-sustaining. The lake trout populations in Lake Superior have recently been declared recovered and self-sustaining. Lake trout are reproducing successfully in portions of Lake Huron and Ontario, but the number of young produced annually and surviving to reproductive age is not yet sufficient to support numerical population goals established in the FCGO for lake trout in these lakes. Lake trout abundance, yield, or biomass reference values are now generally met throughout the lower four Great Lakes by stocking lake trout.

Schneider, C.P., T. Schaner, S. Orsatti, S. Lary, and D. Busch. 1998. A management strategy for Lake Ontario lake trout. Great Lakes Fish. Comm. 23 p.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): biota, fish
Related Issue(s): contaminants & pathogens, nutrients, exotics, habitat
SOLEC Grouping(s): **open waters**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 6: Degradation of benthos

Last Revised
March 13, 2000

Deformities, Eroded Fins, Lesions and Tumors (DELT) in Nearshore Fish (Indicator ID: 101)

Measure
Frequency of tumors and other related anomalies in nearshore fish.

Purpose
This indicator will assess the combination of deformities, eroded fins, lesions and tumors (DELT index) in nearshore fish, and it will be used to infer areas of degraded habitat within the Great Lakes.

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

Endpoint
When the incidence rate of fish tumors or other deformities do not exceed rates at unimpacted control sites and when survey data confirm the absence of neoplastic or preneoplastic liver tumors in bullheads or suckers. (IJC Delisting criteria, see IJC 1996)

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

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

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

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

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

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

1. An intestinal or liver tumor prevalence of >5% (rate at reference site exceeded by >5%) occurs in common native nearshore species of benthic dwelling fishes (e.g., brown bullhead, black bullhead, white sucker, and several species of redhorse). Tumors are neoplasms of intestinal, bile duct, or liver cells, as determined by histopathology.

2. A prevalence of lip tumors >10%, or of overall external tumors >15% in any of the benthic species listed in 1 above. Tumors are papillomas or other neoplasms, as determined by histopathology.

3. A DELT (deformities, eroded fins, lesions, and tumors) Index (Ohio EPA) of > 0.5%. The fish species used in compiling the index is not limited to the species listed in 1 above.

Comments
This indicator was prepared using information from:

Edsall, T., and M. Charlton. 1997. Nearshore waters of the Great Lakes. State of the Lakes Ecosystem Conference ‘96 Background Paper. ISBN 0-662-26031-7.

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

Unfinished Business

< A discussion of the potential limitations associated with this indicator (e.g., data collection, cost, etc.) Needs to be included.

< On what basis can the subjective tags of “good” and “poor” be applied towards progress of the Beneficial Use Impairment.

Relevancies

Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters**, **nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s): 4: Fish tumors and other deformities

Last Revised

March 8, 2000

Benthos Diversity and Abundance (Indicator ID: 104)

Measure
Species diversity and abundance in the aquatic oligochaete community.

Purpose
This indicator will assess species diversity and abundance in the aquatic oligochaete community, and it will be used to infer the relative health of the benthic community.

Ecosystem Objective
This indicator addresses the general FCGO to protect and enhance fish habitat, achieve no net loss of the productive capacity of habitat supporting fish communities, and restore damaged habitats. This indicator supports Annex 2 of the GLWQA.

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

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

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

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

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

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

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

Relevancies
Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens, nutrients, habitat
SOLEC Grouping(s): **open waters**, **nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s):
Beneficial Use Impairment(s): 6: Degradation of benthos

Last Revised
March 8, 2000

Phytoplankton Populations (Indicator ID: 109)

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

Purpose
This indicator will assess the species and size composition of phytoplankton populations in the Great Lakes, and it will be used to infer the impact of nutrient enrichment, contamination and invasive exotic predators on the Great Lakes ecosystem.

Ecosystem Objective
Mesotrophic to oligotrophic conditions are needed to maintain healthy food-web dynamics and habitat integrity of the Great Lakes ecosystem. Goals of phosphorus control are to maintain an oligotrophic state and relative algal biomass of Lakes Superior, Huron and Michigan, and to maintain algal biomass below that of a nuisance condition in Lakes Erie and Ontario (GLWQA Annex 3). This indicator also supports Annex 2 of the GLWQA.

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

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

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

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

Interpretation

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

This indicator was prepared using information from:
M. Munawar, I.F. Munawar, P. Ross & R. Dermott. 1992. Exploring aquatic ecosystem health: A multi-trophic and an ecosystemic approach. J. Aquat. Ecosyst. Health. 1:237-252

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

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

Relevancies
Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens, nutrients, exotics
SOLEC Grouping(s): **open waters**, **nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of Phosphorus, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 8: Absence of excess phosphorus
GLFC Objective(s):
Beneficial Use Impairment(s): 13: Degradation of phyto/zooplankton populations

Last Revised
March 8, 2000

Phosphorus Concentrations and Loadings (Indicator ID: 111)

Measure
Total phosphorus levels (ug/L) in the springtime open waters, and annual total phosphorus loads to each lake.

Purpose
This indicator will assess the total phosphorus levels and loadings in the Great Lakes and it will be used to support the evaluation of trophic status and food web dynamics in the Great Lakes.

Ecosystem Objective
Goals of phosphorus control are to maintain an oligotrophic state and relative algal biomass of 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 in bays and in other areas wherever they occur (GLWQA Annex 3). The IJC developed the following delisting guideline for eutrophication or undesirable algae: 'no persistent water quality problems (e.g., dissolved oxygen, depletion of bottom waters, nuisance algal blooms or accumulations, and decreased water clarity) attributed to cultural eutrophication.'

The indicator also supports Annexes 1, 2 and 13 of the GLWQA.

Endpoint
Maximum annual phosphorus loadings to the Great Lakes that would allow achievement of the stated goals (above) are: Lake Superior - 3400 tonnes, Lake Huron (main lake) - 2800 tonnes, Lake Michigan - 5600 tonnes, Lake Erie - 11,000 tonnes, Lake Ontario - 7000 tonnes (GLWQA, Annex 3). If these loading rates are maintained, the expected concentration of total phosphorus in the open waters of each lake are: Lake Superior - 5 ug/l, Lake Huron - 5 ug/l, Lake Michigan - 7 ug/l, Lake Erie Western Basin - 15 ug/l, Lake Erie Central Basin - 10 ug/l, Lake Erie Eastern Basin - 10 ug/l, Lake Ontario - 10 ug/l (IJC 1980).

Features
Analysis of phosphorus concentrations to the Great Lakes is ongoing and reliable, but insufficient monitoring of tributaries has been undertaken since 1993 to calculate reliable loading estimates. Current methodology used for analysis is adequate. This indicator provides information to infer the baseline potential productivity of each lake and linkages to future biological problems related to a potential return to excess nutrient loads. Also, the filtering effects of new colonizing species -- zebra and quagga mussels -- appear to exacerbate the effects of declining phosphorus loading (hence declining lake productivity). Measurements and reporting must reliably reflect spatio-temporal differences on scales needed to effectively address the ecosystem objective. Particular emphasis should be placed on open-lake data collected in the spring of the year, and comparison should be made with the GLWQA objectives. Biannual survey data are available for 1982 to present.

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

Limitations
Tributary monitoring is currently (2000) insufficient to evaluate loadings of phosphorus.

A research effort should be undertaken to understand the effects of zebra mussels on phosphorus dynamics in the Great Lakes, and to then incorporate those effects into existing water quality models. The revised models should then be used to reanalyze the relationships between annual phosphorus loadings, the expected resultant phosphorus concentrations in the open waters, and the potential for nuisance growths of algae.

Interpretation
Desirable outcomes are the absence of blooms of undesirable algae and total phosphorus concentrations and loadings that do not exceed the target levels specified in the GLWQA. Remote sensing and satellite imagery can be used to identify algae blooms, which may then be correlated to phosphorus concentrations or increased loadings.

Comments
This indicator was prepared using information in:

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

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

IJC. 1980. Phosphorus Management for the Great Lakes. Final report of the Phosphorus Management Strategies Task Force to the IJC Great Lakes Water Quality Board and Great Lakes Science Advisory Board.

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): nutrients
SOLEC Grouping(s): **open waters**, **nearshore waters**, coastal wetlands
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of phosphorus, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 8: Absence of excess phosphorus
GLFC Objective(s): Erie
Beneficial Use Impairment(s): 8: Eutrophication or undesirable algae, 9: Restrictions on drinking water consumption or taste and odour problems, 11: Degradation of aesthetics, 13: Degradation of phyto/zooplankton populations

Last Revised

March 8, 2000

Contaminants in Young-of-the-Year Spottail Shiners
(Indicator ID: 114)

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

Purpose
This indicator will assess the levels of PBT chemicals in young-of-the-year spottail shiners, and it will be used to infer local areas of elevated contaminant levels and potential harm to fish-eating wildlife.

Ecosystem Objective
Forage fish concentrations of PBT chemicals should not pose risk to fish-eating wildlife. This indicator supports Annexes 1, 2 and 12 of the GLWQA.

Endpoint

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

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

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

Interpretation

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

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

Relevancies
Indicator Type: pressure
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **nearshore waters**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 23, 2000

Contaminants in Colonial Nesting Waterbirds (Indicator ID: 115)

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

Purpose
This indicator will assess chemical concentration levels in a representative colonial waterbird, and it will be used to infer the impact of these contaminants on colonial waterbird physiology and population characteristics.

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

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

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

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

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

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

Comments
Contaminant concentrations in most colonial-nesting, fish-eating birds are at levels where gross ecological effects, such as eggshell thinning, reduced hatching and fledging success, and population declines, are no longer apparent. Greater reliance for detecting biological effects of contaminants is being put upon physiological and genetic biomarkers. These are not as well characterized, nor are they understood as easily by the public. Other complementary species include: Double-crested Cormorant (Phalacrocorax auritus), Common Tern (Sterna hirundo), Caspian Tern (Sterna caspia) and Black-crowned Night-Heron (Nycticorax nycticorax). The Herring Gull egg contaminants dataset is the longest running continuous contaminants dataset for wildlife in the world.

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

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

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

Relevancies
Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters**, **nearshore waters**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s): Erie
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 5: Bird or animal deformities or reproductive problems

Last Revised
Feb. 23, 2000

Zooplankton Populations (Indicator ID: 116)

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

Purpose
This indicator will assess characteristics of the zooplankton community, and it will be used to infer over time changes in vertebrate or invertebrate predation, system productivity, energy transfer within the Great Lakes, or other food web dynamics.

Ecosystem Objective
Maintain the biological integrity of the Great Lakes and to support a healthy and diverse fishery as outlined by the Goals and Objectives of the LaMPs and Great Lakes Fishery Commission. This indicator supports Annex 2 of the GLWQA.

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

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

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

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

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

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

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

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

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

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McCauley, E. and J. Kalff. 1980. Empirical relationships between phytoplankton and zooplankton biomass in lakes. Can. J. Fish. Aquat. Sci. 38: 458-463.

McQueen, D.J., J.R. Post, and E.L. Mills. 1986. Trophic relationships in freshwater pelagic ecosystems. Can. J. Fish. Aquat. Sci. 43: 1571-1581.

Mills, E.L., D.M. Green & A. Schiavone Jr. 1987. Use of zooplankton size to assess the community structure of fish populations in freshwater lakes. North Am. J. Fish. Man. 7: 369-378.

Yan, N.D. 1985. Empirical predicaiton of crustacean zooplankton biomass in nutrient-poor Canadian shield lakes Can. J. Fish. Aquat. Sci. 43: 788-796.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens, nutrients, exotics
SOLEC Grouping(s): **open waters**, **nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s):
Beneficial Use Impairment(s): 13: Degradation of phyto/zooplankton populations

Last Revised
Feb. 23, 2000

Atmospheric Deposition of Toxic Chemicals (Indicator ID: 117)

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

Purpose
This indicator will estimate the annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes, and it will be used to infer potential impacts of toxic chemicals from atmospheric deposition on the Great Lakes aquatic ecosystem, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Ecosystem Objective
The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life. This indicator supports Annexes 2, 12, 15 and 17 of the GLWQA.

Endpoint
When atmospheric concentrations of toxic chemicals associated with existing water quality criteria are no longer measurable above naturally-occurring levels by current technology.

Features
This indicator will track whether concentrations of priority toxic chemicals are, as a group, decreasing, staying the same, or increasing in open waters over time. The chemicals of interest include, but are not limited to, PCBs, deildrin, chlordane, DDT and metabolites, hexachlorobenzene, toxaphene and mercury. Loadings will be calculated based on 1) measured atmospheric concentrations of the chemicals and 2) wet and dry deposition rates using techniques described in the "Chemicals of Concern" chapter of the Lake Superior Stage II LaMP. The indicator data will also demonstrate the magnitudes of the trends in the loadings of toxic chemicals from the air to the water. The magnitudes of the trends are expressed as a "half-fold time," or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals.

Illustration

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

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

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

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

Wet deposition (W) is calculated as:

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

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

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

Dry deposition of particles is calculated from:

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

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

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

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

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

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

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

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

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

IADN Quality Assurance Program Plan. 1994. Environment Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.

IADN Steering Committee. 1997. Technical Summary of Progress Under the Integrated Atmospheric Deposition Program 1990-1996. R.M. Hoff, ed., Environment Canada, 4905 Dufferin Street, Downsview, Ontario, Canada M3H 5T4, 101p.
(URL: http://airquality.tor.ec.gc.ca/IADN/IP2.htm)

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

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

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

Unfinished Business

- Need to provide a detailed description of how data will be displayed graphically. For example, will the illustration consist of various colored plottings on a map or a bar chart to convey the relative abundance?

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, water
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 15: Airborne toxic substances, 17: Research and development
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
March 8, 2000

Toxic Chemical Concentrations in Offshore Waters (Indicator ID: 118)

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

Purpose
This indicator will assess the concentration of priority toxic chemicals in offshore waters, and it will be used to infer the potential impacts of toxic chemicals on the Great Lakes aquatic ecosystem, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Ecosystem Objective
The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life. This indicator supports Annexes 1 and 12 of the GLWQA.

Endpoint
When concentrations of toxic chemicals associated with existing water quality criteria in the offshore waters of the Great Lakes are no longer measurable above naturally-occurring levels by current technology.

Features
This indicator will track whether concentrations of the IJC priority toxic chemicals are, as a group, decreasing, staying the same, or increasing in open waters over time. The chemicals of interest include, but are not limited to, PCBs, deildrin, chlordane, DDT and metabolites, hexachlorobenzene, toxaphene and mercury. The indicator data will also demonstrate the magnitudes of the trends of the various chemicals. The magnitudes of the trends are expressed as a “half-fold time,” or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals. Monitoring for this indicator will occur during the two year periods between SOLEC. Every two years, water concentrations of zero discharge and lakewide remediation chemicals should be monitored throughout the offshore waters of Lake Superior, for comparison with an appropriate baseline. Sampling should be conducted during spring, isothermal conditions, as maximum concentrations have been reported during this time.

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

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

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

Comments

Unfinished Business
< Need to provide a detailed description of how data will be displayed graphically. For example, will the illustration consist of various colored plottings on a map or a bar chart to convey the relative abundance?

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
March 8, 2000

Concentration of Contaminants in Sediment Cores (Indicator ID: 119)

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

Purpose
This indicator will assess the concentrations of toxic chemicals in sediments, and it will be used to infer potential harm to aquatic ecosystems by contaminated sediments, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Ecosystem Objective
The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life. And, GLWQA Annex 14 Objective asks to identify the nature and extent of sediment pollution of the Great Lakes System. This indicator also supports Annexes 2, 7 and 12 of the GLWQA.

Endpoint
When sediment concentrations of toxic chemicals associated with existing water quality criteria are no longer measurable above naturally-occurring levels by current technology.

Features
This indicator will track whether concentrations of the toxic chemicals are, as a group, decreasing, staying the same, or increasing in open waters over time. The chemicals of interest include, but are not limited to, PCBs, deildrin, chlordane, DDT and metabolites, hexachlorobenzene, toxaphene and mercury. The indicator data will also demonstrate the magnitudes of the trends of the various chemicals. The magnitudes of the trends are expressed as a “half-fold time,” or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals.

In the nearshore areas and harbours and bays, cores would be collected every 10 years from sites selected for index monitoring. Index sites should include areas where sediment sampling would provide added value to contaminant investigations, for example, sites previously monitored for contaminants in fish. Sites would also be chosen based on sediment type, expected sedimentation rates, and proximity to potential sources. Cores would be sectioned, dated and analyzed for the toxic chemicals.

Certain estuaries, bays, and harbours on the lakes, are designated as Areas of Concern because of past or on-going pollution problems. Sediment contamination in these areas, taken together, represent cumulative impacts to productive habitat areas. In addition, Areas of Concern can serve as contaminant source areas to the rest of the Lakes. Application of the sediment indicator at Areas of Concern is intended to integrate the information gathered by RAP monitoring efforts to give a lakewide picture for these important habitat areas.

Illustration
The sediment concentrations would be depicted using the standard tables and figures showing the change in concentration at different depths. Only the upper segment of the core would be compared to the yardstick or local standard. In addition, a set of maps showing locations and concentrations of sediments in the nearshore areas and a set of maps showing sediment chemical concentrations in the Areas of Concern would serve to illustrate the indicator.

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

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

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

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

Unfinished Business

< For the presentation of the indicator "standard tables and figures" should be defined or the text modified to be more descriptive (e.g., Sediment concentrations at each site, by depth, will be displayed on a bar graph. Current detection limits will be clearly marked).

Relevancies

Indicator Type: pressure
Environmental Compartment(s): sediments
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters**, **nearshore waters**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 7: Dredging, 11: Surveillance and monitoring, 12: Persistent toxic substances, 14: Contaminated sediment
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s): 6: Degradation of benthos, 7: Restrictions on dredging activities

Last Revised

March 8, 2000

Contaminant Exchanges Between Media: Air to Water, and Water to Sediment (Indicator ID: 120)

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

Purpose
This indicator will estimate the loadings of priority pollutants to the Great Lakes, and it will be used to infer the potential harm these contaminants pose to human, animal and aquatic life within the Great Lakes, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Ecosystem Objective
The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life. This indicator supports Annexes 1, 12, 14, 15 and 17 of the GLWQA.

Endpoint
When concentrations of priority chemicals within the Great Lakes are no longer measurable above naturally-occurring levels by current technology.

Features
This indicator will track whether concentration trends of the toxic chemicals between media are, as a group, decreasing, staying the same, or increasing in open waters over time. The chemicals of interest include, but are not limited to, PCBs, deildrin, chlordane, DDT and metabolites, hexachlorobenzene, toxaphene and mercury. It combines the concentration trends in air (from indicator 117), water (from indicator 118), and sediments (from indicator 119) towards an assessment of overall trend in the loadings of these chemicals to the system. The indicator data will also demonstrate the magnitudes of the trends of the various chemicals. The magnitudes of the trends are expressed as a “half-fold time,” or time to which the concentration of the chemical is decreased by a factor of two. The time which is most relevant to virtual elimination is the longest half-fold time of the measured chemicals.

Illustration

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

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

Interpretation

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

$$f = M/3\ V_i Z_i$$

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

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

$Z_{water} = 1/H$ (H = Henry’s law constant)

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

where

$D_{sediment}$ = density of the sediment

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

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

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

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

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

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, water, sediments
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **open waters**, **nearshore waters**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances, 14: Contaminated sediment, 15: Airborne toxic substances, 17: Research and development
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
March 8, 2000

Wastewater Pollution (Indicator ID: 7059)

Measure
Loadings of metals, phosphorus, BOD and organic chemicals that are released by municipal sewage treatment plants and industrial direct dischargers, into water courses in the Great Lakes basin.

Purpose
To assess the loadings of wastewater pollutants discharged into the Great Lakes basin, and to infer inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

Ecosystem Objective
Sustainable development and healthy ecosystems through support for Annexes 1, 2, 3 and 12 of the GLWQA.

Endpoint
High quality wastewater discharges that approach the ambient quality of the 'sink' they are being discharged to (or the source from which they originated) is a desired endpoint that can best be achieved through pollution prevention ad resource conservation.

Features
Pollutant loadings in wastewater represent waste from land use activities that contaminate the Great Lakes. SOLEC '96 Land Use Background paper discusses the levels of wastewater loading to the Great Lakes. This indicator is related to indicator 7056, Water Withdrawal, since the quality of wastewater effluent is generally improved in total loadings when the hydraulic volume of wastewater is reduced.

Illustration
The indicator will be presented as graphs that display loadings over time by jurisdiction, by lake basin and for the overall basin.

Limitations
Although data are largely available, they are not collected on a necessarily comparable fashion for both the U.S. and Canada. Some work is required to ensure that Ontario data is consistent with the U.S. Since much industrial wastewater flows to municipal sewage treatment facilities the efficiency of these in reducing waste can be hidden.

Interpretation
Wastewater treatment is dependant on the quality of incoming wastewater sources, the state of the technology to process the wastewater and other factors such as fugitive leaks that can increase volumes dramatically at certain times and result in deterioration of the quality of wastewater. The number of hours of by-pass at wastewater plants may be added as another measure, although this addresses the state of the treatment infrastructure more than waste reduction itself. A historical reference of loadings will be used as a benchmark for the indicator.

Comments

Unfinished Business
< Need to determine from where in the Great Lakes basin the information will be collected and how frequently.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): contaminants & pathogens, nutrients
SOLEC Grouping(s): **nearshore waters**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of phosphorus, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances, 8: Absence of excess phosphorus
GLFC Objective(s):
Beneficial Use Impairment(s): 8: Eutrophication and undesirable algae, 11: degradation of aesthetics

Last Revised
Feb. 23, 2000

Sediment Available for Coastal Nourishment (Indicator ID: 8142)

Note: This indicator is listed as both a Nearshore Waters and Nearshore Terrestrial indicator.

Measure
Streamflow and suspended sediments at the mouth of major tributaries and connecting channels.

Purpose
To assess the amount of water and suspended sediment entering the Great Lakes through major tributaries and connecting channels, and to estimate the amount of sediment available for transport to nourish coastal ecosystems.

Ecosystem Objective
This indicator supports Annex 2 of the GLWQA.

Endpoint
Functioning longshore transport process necessary for healthy coastal ecosystems.

Features
The role of streamflow in sediment transport and nourishment of coastal ecosystems is needed to evaluate and predict the health of the ecosystems. Data for the streamflow and suspended sediments to the lakes from the largest tributaries and for the total combined flow for each lake will be collected every three years. Trends will indicate a change in the amount of sediments available for coastal nourishment. Monitoring of streamflow and sediment load is one of the oldest and most well established programs in both the United States and Canada.

Illustration
Data for the streamflow and suspended sediments to the lakes from the largest tributaries and for the total combined flow for each lake will be depicted as line graphs.

Limitations
Recent dramatic cuts in the Canadian budget may influence this monitoring. An evaluation is needed to prioritize the location of monitoring locations.

Interpretation
Once baseline values are determined, streamflow at the mouths of specified tributaries and concentration of suspended sediments will be tracked.

Comments
Data may be eventually used to help evaluate the impacts of climate change.

Unfinished Business
< Need to provide a unit of measurement to increase specificity.
< Need to determine a quantifiable endpoint.

Relevancies
Indicator Type: state
Environmental Compartment(s): water, sediments
Related Issue(s): habitat
SOLEC Grouping(s): **nearshore waters**, **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Coastal Wetland Invertebrate Community Health (Indicator ID: 4501)

Measure
Relative abundance of sensitive taxa (e.g., mayflies, caddisflies), tolerant taxa (e.g., Chironomini as a proportion of total Chironomidae abundance, Isopoda), richness of specific taxa, and functional feeding groups (e.g., herbivores, detritivores, carnivores), working towards the development of an Index of Biotic Integrity (IBI).

Purpose
To assess the diversity of the invertebrate community, especially aquatic insects, and to infer habitat suitability and biological integrity of Great Lakes coastal wetlands.

Ecosystem Objective
Restore and maintain the diversity of the invertebrate community of Great Lakes coastal wetlands. (GLWQA Annexes 2 and 13).

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

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

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

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

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

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

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

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

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): biota

Related Issue(s): habitat
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 6: Degradation of benthos

Last Revised
Feb. 23, 2000

Coastal Wetland Fish Community Health (Indicator ID: 4502)

Measure
An Index of Biotic Integrity (IBI) will be developed based on measures of species richness and abundance, percent exotic species, percent phytophils and other appropriate parameters.

Purpose
To assess the fish community diversity, and to infer habitat suitability for Great Lakes coastal wetland fish communities.

Ecosystem Objective
Restore and maintain the diversity of the fish community of Great Lakes coastal wetlands. (GLWQA Annexes 2 and 13)

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

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

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

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

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

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

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): exotics, habitat
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Deformities, Eroded Fins, Lesions and Tumors (DELT) in Coastal Wetland Fish (Indicator ID: 4503)

Measure
Numbers and percent of DELT in coastal wetland fish.

Purpose
To assess the combination of deformities, eroded fins, lesions and tumours (DELT index) in fish of Great Lakes coastal wetlands, and to infer ecosystem health of Great Lakes coastal wetlands.

Ecosystem Objective
Restore the health of fish of Great Lakes coastal wetlands. (GLWQA Annexes 2, 12, 13 and 17)

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

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

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

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

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

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

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 13: Pollution from non-point sources, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s): 4: fish tumors or other deformities

Last Revised
Feb. 23, 2000

Amphibian Diversity and Abundance (Indicator ID: 4504)

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

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

Ecosystem Objective
Restore and maintain the diversity of Great Lakes coastal wetland amphibian communities. Breeding populations of amphibian species across their historical range should be sufficient to ensure continued success of each species. (GLWQA Annex 13)

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

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

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

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

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

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

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

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

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): biota

Related Issue(s): habitat
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Contaminants in Snapping Turtle Eggs (Indicator ID: 4506)

Measure
Concentrations of organochlorine chemicals and mercury in snapping turtle eggs.

Purpose
To assess the accumulation of organochlorine chemicals and mercury in snapping turtle eggs, and to infer the extent of organochlorine chemicals and mercury in food webs of Great Lakes coastal wetlands.

Ecosystem Objective
Snapping turtle populations in Great Lakes coastal wetlands and populations observed at a clean inland reference site, such as Algonquin Provincial Park, Ontario, should not exhibit significant differences in concentrations of organochlorine chemicals and mercury, thereby ensuring hatching success and low abnormality rates. (GLWQA Annexes 1, 12 and 13).

Endpoint

a) Mean wet weight concentrations in snapping turtle eggs should not exceed*:

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

b) Mean wet weight concentrations in plasma from snapping turtle eggs should not exceed*:

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

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

Endpoints for mercury have yet to be developed.

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

Illustration
Mean concentration of organochlorine chemicals and mercury at the uncontaminated reference site (e.g., Algonquin Provincial Park) superimposed over concentrations from representative sites from the Lakes and connecting channels. This would be presented as a bar graph showing sites and concentrations, along with the mean concentration for the reference site as a comparison.

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

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

Comments

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

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

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

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances, 13: Pollution from non-point sources
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb 23, 2000

Wetland-Dependent Bird Diversity and Abundance
(Indicator ID: 4507)

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

Purpose
To assess the wetland bird species composition and relative abundance, and to infer the condition of coastal wetland habitat as it relates to the health of this ecologically and culturally important component of wetland communities.

Ecosystem Objective
Restore and maintain the diversity of Great Lakes coastal wetland bird communities. Breeding populations of bird species across their historical range should be sufficient to ensure continued success of each species. (GLWQA Annex 2)

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

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

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

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

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

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

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

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

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): biota

Related Issue(s): habitat
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Coastal Wetland Area by Type (Indicator ID: 4510)

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

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

Ecosystem Objective
Reverse the trend toward loss of Great Lakes coastal wetlands, ensuring adequate representation of wetland types across their historical range. (GLWQA Annexes 2 and 13)

Endpoint
No net loss of coastal wetlands due to human actions and, in the future, a net gain to coastal wetlands due to restoration activities, recognizing that a reference year needs to be selected.

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

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

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

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

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

Interpretation
This indicator needs to be evaluated in terms of both wetland quality and extent. While some wetlands may decrease in both area and quality due to the lack of water level fluctuation, as on Lake Ontario, the area of other wetlands could remain within the range determined by natural water level fluctuations, but be degraded by other factors, such as sedimentation, excessive nutrients, or invasive species. When interpreting the data, the other coastal wetland indicators that evaluate wetland quality need to be considered. For measuring the variable in a most superficial way, the extent of the wetland remaining could be estimated to the nearest 10% and then divided by 10, providing a score of 1-10. For example, a wetland type that remains at roughly 80% of its original size within a particular water level regime would have a score of 80/10=8.

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

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): water, land
Related Issue(s): habitat
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Gain in Restored Coastal Wetland Area by Type (Indicator ID: 4511)

Measure
Gain in restored wetland area by type.

Purpose
To assess the amount of restored wetland area, and to infer the success of conservation and rehabilitation efforts.

Ecosystem Objective
Sufficient gain in restored wetland area to ensure adequate representation of coastal wetlands by type across their historical range. (GLWQA Annexes 2 and 13)

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

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

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

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

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

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

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

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

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): water, land
Related Issue(s): habitat, stewardship
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Presence, Abundance & Expansion of Invasive Plants
(Indicator ID: 4513)

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

Purpose
To assess the decline of vegetative diversity associated with an increase in the presence, abundance, and expansion of invasive plants, and to be used as a surrogate measure of quality of coastal wetlands which are impacted by coastal manipulation or input of sediments.

Ecosystem Objective
Coastal wetlands throughout the Great Lakes basin should contain low numbers of invasive plant species with low levels of coverage. (GLWQA Annexes 2 and 13)

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

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

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

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

Interpretation
A ranking could be developed based on a combined score of 1) the number of invasive plant species, 2) the coverage value of coastal wetlands dominated by invasive plant species and 3) whether the invasive plants are native or non-native.

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

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): exotics, habitat
SOLEC Grouping(s): **coastal wetlands**, nearshore terrestrial
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Sediment Flowing into Coastal Wetlands (Indicator ID: 4516)

Measure
Suspended Sediment Unit Area Yield (tonnes/km^2 of upstream watershed) for a representative set of existing monitoring sites just upstream of coastal wetlands.

Purpose
To assess the severity of sediment yields flowing into coastal wetlands and potential impact on wetland health.

Ecosystem Objective
To maintain and restore healthy coastal wetlands which are highly dependent on appropriate sediment loads. (GLWQA Annexes 1, 2 and 13)

Endpoint
Wetlands require some sediment to maintain barriers and elevation against scour etc., so the reference value is not zero. A desired endpoint can be set from unit area yields to representative wetlands without sedimentation problems.

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

Illustration
This indicator could be displayed graphically as tonnes of sediment per km^2 of coastal wetland watersheds (y axis) versus time (x axis). The desired reference point or endpoint could be indicated on the y axis and across the graph.

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

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

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

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water, sediments
Related Issue(s): habitat
SOLEC Grouping(s): **coastal wetlands**, nearshore terrestrial
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Nitrate and Total Phosphorus Into Coastal Wetlands

(Indicator ID: 4860)

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

Purpose
To assess the amount of nitrate and total phosphorus flowing into Great Lakes coastal wetlands, and to infer the human influence on nutrient levels in the wetlands.

Ecosystem Objective
Maintenance and restoration of more natural levels of nutrients to maximize: species and community diversity, wetland integrity and wetland values. (GLWQA Annexes 3 and 13)

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

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

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

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

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

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

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

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

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): nutrients
SOLEC Grouping(s): **coastal wetlands**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of phosphorus, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 8: Absence of excess phosphorus
GLFC Objective(s):
Beneficial Use Impairment(s): 8: Eutrophication or undesirable algae

Last Revised
Feb. 23, 2000

Water Level Fluctuations (Indicator ID: 4861)

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

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

Purpose
To assess the lake level trends that may significantly affect components of wetland and nearshore terrestrial ecosystems, and to infer the effect of water level regulation on emergent wetland extent.

Ecosystem Objective
To maintain and restore healthy coastal wetlands whose existence and integrity depend on naturally fluctuating water levels (GLWQA Annexes 2 and 17).

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

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

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

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

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

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

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

Comments

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

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

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): habitat, climate change
SOLEC Grouping(s): **coastal wetlands**, **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised

Feb. 23, 2000

Area, Quality, and Protection of Lakeshore Communities
(Indicator ID: 8129)

Measure
Area, quality, and protected status of twelve special lakeshore communities occurring within 1 kilometre (km) of shoreline. The twelve special lakeshore communities are sand beaches, sand dunes, bedrock and cobble beaches, unconsolidated shore bluffs, coastal gneissic rocklands, limestone cliffs and talus slopes, lakeplain prairies, sand barrens, arctic-alpine disjunct communities, Atlantic coastal plain disjunct communities, shoreline alvars, and islands.

Purpose
To assess the changes in area and quality of the twelve lakeshore communities, and to infer the success of management activities associated with the protection of some of the most ecologically significant habitats in the Great Lakes terrestrial nearshore.

Ecosystem Objective
This indicator supports Annex 2 of the GLWQA.

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

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

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

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

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

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

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): land, biota
Related Issue(s): habitat, stewardship
SOLEC Grouping(s): **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Extent of Hardened Shoreline (Indicator ID: 8131)

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

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

Ecosystem Objective
Shoreline conditions should be healthy to support aquatic and terrestrial plant and animal life, including the rarest species. This indicator supports Annex 2 of the GLWQA.

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

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

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

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

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

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

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

Relevancies
Indicator Type: pressure
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): nearshore terrestrial, land use
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Nearshore Land Use (Indicator ID: 8132)

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

Purpose
To assess the types and extent of major land uses within 1 km from shore, and to identify real or potential impacts of land use on significant natural features or processes, particularly on the twelve special lakeshore communities.

Ecosystem Objective
Healthy nearshore terrestrial ecological communities will be maintained. This indicator supports Annex 2 of the GLWQA.

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

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

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

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

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

Comments
The twelve special lakeshore communities are sand beaches, sand dunes, bedrock and cobble beaches, unconsolidated shore bluffs, coastal gneissic rocklands, limestone cliffs and talus slopes, lakeplain prairies, sand barrens, arctic-alpine disjunct communities, Atlantic coastal plain disjunct communities, shoreline alvars, and islands.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): **nearshore terrestrial**, land use
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Nearshore Plant and Animal Problem Species (Indicator ID: 8134)

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

Purpose
To assess the type and abundance of plant and animal problem species in landscapes bordering the Great Lakes, and to identify the potential for disruption of nearshore ecological processes and communities.

Ecosystem Objective
Healthy nearshore ecological processes and communities in the Great Lakes should be free of disruptive problem species. Healthy populations of grassland/forest interior bird species should be undisturbed by parasitic species. Preserve/restore larger intact ecosystems to support healthy nearshore ecological processes and communities in the Great Lakes. This indicator supports Annexes 2 and 17 of the GLWQA.

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

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

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

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

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

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

Interpretation
A number of other factors will need to be considered in interpreting this indicator. Changes in abundance, density, and productivity of native nearshore ecological communities are caused by factors other than the degree of habitat fragmentation, the amount of available habitat, and interactions with invasive exotic species. Factors such as connectivity and the survivorship of birds on migration routes and wintering areas will influence abundance density and productivity, and therefore, will affect the interpretation

of this indicator. In general, increases in interior species and decreases in problem species, compared to a baseline of current populations, should be interpreted as good.

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

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

Relevancies
Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): exotics, habitat
SOLEC Grouping(s): **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised
Feb. 23, 2000

Contaminants Affecting Productivity of Bald Eagles (Indicator ID: 8135)

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

Purpose
To assess the number of fledged young, number of developmental deformities, and the concentrations of organic and heavy metal contamination in Bald Eagle eggs, blood, and feathers. The data will be used to infer the potential for harm to other wildlife and human health through the consumption of contaminated fish.

Ecosystem Objective
This indicator supports Annexes 2, 12 and 17 of the GLWQA.

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

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

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

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

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

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

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

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): open waters, nearshore waters, **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 5: Bird or animal deformities or reproductive problems

Last Revised
Feb. 23, 2000

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

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

Purpose
To assess the amount of natural land cover that falls within 1 km of the shoreline, and to infer the potential impact of artificial coastal structures, including primary and secondary home development, on the extent and quality of nearshore terrestrial ecosystems in the Great Lakes.

Ecosystem Objective
Maintain the health and function of a representative number of shoreline natural land cover types. This indicator supports Annex 2 of the GLWQA.

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

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

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

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

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

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

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

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environment integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 24, 2000

Nearshore Species Diversity and Stability (Indicator ID: 8137)

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

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

Ecosystem Objective
This indicator supports Annex 2 of the GLWQA.

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

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

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

Limitations
Comprehensive data is not available for all species groups, and data collection is laborious and largely volunteer-based. Even for the best data sets, such as the data set on breeding birds, coverage is incomplete in more remote areas. Historical data on regeneration rates is highly site-specific, and available for relatively few sites.

Interpretation
These data can be compared to the total number of species that could be expected within each shoreline cell. For some species, population ratios could also be derived as well, as a comparative measure of stress - for example, classing the population of a species within each cell as abundant, common, scarce, or rare. The nature of observed changes over time can indicate different kinds of stresses. For example, a uniform decrease in the diversity of breeding species could indicate a broad-scale stress such as climate change; decreases only on urban fringes while more remote areas stay the same would more likely point to local habitat changes. It would be useful to divide the data between resident and long distance migrant birds in order to separate local from broad impacts.

Comments
As part of the indicator development, priority species, which could be groups of birds, woodland frogs, etc., should be selected.

In regional studies carried out in southern Ontario by the Federation of Ontario Naturalists, this method showed a range in values from 100% of expected species in good habitats to less than 70% in areas with degraded conditions.

Unfinished Business
< Need to develop a more quantitative endpoint.

Relevancies
Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): exotics
SOLEC Grouping(s): **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity

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

Last Revised
Feb. 24, 2000

Community/Species Plans (Indicator ID: 8139)

Measure
Number of plans that are needed, developed, and implemented to maintain or restore high quality, natural nearshore communities — those within 1 kilometre (km) of the shoreline — and federally/nationally listed endangered, threatened, and vulnerable species.

Purpose
To assess the number of plans that are needed, developed, and implemented to protect, maintain or restore high quality, natural nearshore communities and federally listed endangered, threatened, and vulnerable species, and to infer the degree of human stewardship toward those communities and species.

Ecosystem Objective
Programs should be responsive to the degradation of shoreline communities and species.

Endpoint
Implementation of plans that contained recommended action steps and associated timetables to maintain/recover all significant nearshore natural communities and endangered/threatened/vulnerable species populations identified to date within the nearshore area.

Features
This indicator will compare the number of plans that are needed, developed, and implemented over time. Plans are needed for any species or community that is officially designated as endangered, threatened, or vulnerable (rare) at the federal/national level. The plans will describe the existing community/species status by addressing natural quality, threats, signs of disturbance; natural diversity; rare species (communities) and population size; reproductive success, threats, and recovery needs (species); and recommended action steps. Well-crafted plans will enable monitoring and appropriate conservation measures over time. Implementation of these plans is defined as tangible, on-the-ground management activities that can be shown to be making a measurable difference in the community/species status.

Illustration
To illustrate this indicator, a bar chart will be presented that summarizes the number of plans needed, developed, and implemented for each lake, and tracks progress over time.

Limitations
Tracking the communities/species needing plans and with plans developed should be relatively easy, in conjunction with the federal/national agencies with responsibilities for endangered species. Collecting and analyzing data on implementation in a consistent way may be more difficult.

Interpretation
This indicator should provide a relatively straightforward measure of the attention devoted to communities/species at risk. However, the actual success of these measures will depend largely on the adequacy of the plans and their implementation. Research should be encouraged to address the relationship between the number of plans implemented and the actual maintenance/recovery of natural communities and endangered/threatened/vulnerable species populations.

Comments

Unfinished Business
< Need to determine a reference value that will be used to quantify this endpoint. For example, the endpoint for this indicator might be the implementation of a certain percentage of plans from a total number identified as needed during a baseline year. Or the reference value could be implementation of all plans developed during the previous year.

Relevancies
Indicator Type: human activity
Environmental Compartment(s): biota
Related Issue(s): stewardship
SOLEC Grouping(s): **nearshore terrestrial**, societal
GLWQA Annex(es):
IJC Desired Outcome(s): 6: Biological community integrity and diversity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Shoreline Managed Under Integrated Management Plans
(Indicator ID: 8141)

Measure
Percent of shoreline managed under an integrated shoreline management plan. An integrated shoreline management plan is one that includes consideration of coastal processes, aquatic habitat, and designates appropriate setbacks, etc. and is incorporated into local planning documents (e.g. a municipal Official Plan).

Purpose
To assess the amount of Great Lakes shoreline managed under an integrated management plan, and to infer the degree of stewardship of shoreline processes and habitat.

Ecosystem Objective
Programs should be responsive to the degradation of shoreline communities and species.

Endpoint
The target is 100% of shoreline under "good" pro-active management.

Features
This indicator will track trends in integrated shoreline management plans over time. It will point to areas of the Great Lakes shoreline that are subject to poor or no coastal management. These trends can be used to direct future shoreline management activities.

Illustration
For each of the lakes, this indicator will display a map of shorelines and highlight segments under poor, moderate and good management. This indicator could also be displayed using a pie chart that illustrates the percent of shoreline under the three types of management.

Limitations
Information on quality of shoreline management plans has not been measured across the Great Lakes basin. Existence of shoreline management plans indicates an intent to manage the shoreline accordingly, but does not demonstrate actual compliance or implementation. However, an integrative plan, one that is adopted/incorporated into land use planning documents, does demonstrate serious intent. It is difficult to determine compliance with the plan, or calculate how many zoning variances or amendments have been granted, and it would be too much effort to measure. By focusing on integrated plans, this indicator addresses only part of shoreline planning efforts. Other management plans and programs, including efforts of local municipalities, non-government agencies and the private sector could be considered as these are becoming increasingly important and will continue into the future.

Interpretation
To determine the percentage of shoreline under “good” pro-active management, this indicator could use the following 3- tiered ranking: "poor" = no plan at all; "moderate" = an old plan or a new one that has not actually been adopted; and "good" = an integrated plan that has been incorporated into land use documents. This information could be collected through a survey of shoreline management agencies. Results should be easy to present in an understandable format.

Comments
Some initial research on the potential for integrated shoreline management planning by province and states has been done by Patrick Lawrence at University of Waterloo, along with a focus on continued research on the capacity of Ontario municipalities to undertake Great Lakes shoreline management.

Unfinished Business

Relevancies
Indicator Type: human activity
Environmental Compartment(s): land
Related Issue(s): stewardship
SOLEC Grouping(s): **nearshore terrestrial**, land use, societal
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Artificial Coastal Structures (Indicator ID: 8146)

Measure
The number and type of artificial coastal structures (including groynes, breakwalls, riprap, piers, etc) on the Great Lakes shoreline. Artificial coastal structures include structures that extend into shallow waters at an angle from the shoreline, or are placed offshore for the purpose of breaking the force of the waves. They are distinct from the hardened shoreline works described in indicator 8131, Hardened Shoreline, which modify the shoreline edge itself.

Purpose
To assess the number of artificial coastal structures on the Great Lakes, and to infer potential harm to coastal habitat by disruption of sand transport.

Ecosystem Objective
Limit impact to natural features and processes in the terrestrial nearshore and nearshore waters environments. This indicator supports Annex 2 of the GLWQA.

Endpoint
Modification or removal of artificial coastal structures which are shown to negatively affect coastal sand transport, and restoration of natural coastal transport and deposition processes.

Features
This indicator will present trends in the number of coastal structures over time. From aerial photos and existing data sets, a baseline of artificial shoreline structures will be established. Yearly monitoring will be performed to determine if there is an increase or decrease in the structures. An increase will signify potential increased coastal sand transport disruption.

Illustration
A graph with the number of artificial structures on the y axis and the year on the x axis.

Limitations
It may be difficult to monitor the number of structures on a yearly basis and correlate with the degree of disruption of sand transport in specific sites. Monitoring could be done every 3-5 years, or in periods directly following high lake levels, when many of these structures tend to be built.

Interpretation
An increase in the number of artificial shoreline structures in comparison to the baseline will signal a disruption of the coastal process of sand transport.

Comments
Refer to IJC water level reference study for a classification of shore protection types and summaries of the % length by lake and shoreline reach.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): nearshore waters, **nearshore terrestrial**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 24, 2000

Contaminants Affecting the American Otter (Indicator ID: 8147)

Measure
1) Concentrations of heavy metals (e.g., Hg, Pb, Cd) found in hair, blood, liver, and brain of the American otter; and 2) concentrations of DDT and metabolites, PCBs/ PCDFs/PCDDs, Dioxin, and other organic contaminants found in fatty tissues, liver, and blood of the American otter.

Purpose
To assess the contaminant concentrations found in American otter populations within the Great Lakes basin, and to infer the presence and severity of contaminants in the aquatic food web of the Great Lakes.

Ecosystem Objective
This indicator supports Annexes 1, 2, 12 and 17 of the GLWQA.

Endpoint
1) Maintenance of otter populations in the upper lakes, and restoration of sustainable otter populations to lower Lake Michigan, Lake Ontario and Lake Erie watersheds and shorelines; 2) Great Lakes shoreline and watershed populations of American otter should have an annual mean production > 2 young/adult female; and 3) concentrations of heavy metal and organic contaminants should be less than the NOAEL found in tissue samples from mink as compared to otter tissue samples.

Features
American otters are a direct link to organic and heavy metal concentrations in the food chain. The species has primarily a piscivorous diet, but feeds on a wide array of other aquatic organisms. It is also more sedentary than avian species associated with aquatic food chains and subsequently synthesizes contaminants from a smaller area. It has an appropriate application to measure environmental contaminants on a Great Lakes level, but also on a localized scale. Changes in the species population and range are also representative of anthropogenic riverine and lacustrine habitat alterations. Indications of contaminant problems have been noted by decreased population levels, morphological measures (i.e. baculum length) through necropsies and declines in fecundity. Most State resource management agencies perform necropsies to determine an index of fecundity, deformities, growth rates, age and general health of a given population. Fecundity data from necropsies should be expressed by county and provincial management district annually. Limited toxicological studies have been conducted on Great Lakes otter. Trapping data has been intermittently available since 1835 in the Great Lakes region as an index of species abundance. In Ontario and the Great Lake States, except Ohio, trapping success has been used to model populations.

Illustration
Annual trapping success expressed by total killed and number of otter killed/trapper by county and provincial management district adjacent to Great Lake shorelines from 1950 to the present. Contaminant concentrations and trapping success data could be presented as bar charts showing trends over time, or on a map of the Great Lakes basin showing comparative data among management districts.

Limitations
American otters are difficult to maintain for controlled experiments and are highly visible to the public. There is very little toxicological data available on the species for the Great Lakes. Otters have limited populations in the lower Great Lakes. The method of modeling otter populations by harvest success and using indices of fecundity does not accurately measure population levels in the Great Lakes. Little published data exists on the ecology of otters in the Great Lakes region.

Interpretation
Interpretation of this indicator may prove difficult since the ecology of the species and toxicological profiles from the region remain essentially unknown. No data are available on cause and effect linkages for otter in the Great Lakes. Otter are usually compared to contaminant levels in mink because the end points of a toxicological effect are better understood.

Comments
The potential of the American otter as a Great Lakes Indicator makes intuitive sense. However, more information on its ecology and cause and effect linkages to contaminant problems in the Great Lakes region need to be determined to increase the utility of this indicator.

Resource management agencies should be encouraged to search for and monitor otter toilets on or near Great Lake shorelines for activity annually to note changes in distribution and stability in populations in relationship to sub-units of the Great Lakes that are known to be contaminated.

This proposed indicator was the most contentious of the nearshore terrestrial set, with some commenters suggesting that it be dropped, or replaced with monitoring of otter reproduction. In their view, otter reproduction would provide a measure that is more useful in assessing progress toward the GLWQA objectives versus evidence of reductions inferred from chemical analyses and conservative benchmarks. There is also concern that otter contaminant monitoring duplicates the mink indicator.

In response, other reviewers noted that mink are less common than otters in Lake Superior island environments (where they could provide an indicator that would not be influenced by mainland anthropogenic influences), and that mink are extremely problematic to study in the field. Otter differ entirely from mink in their habits and habitats. Otter are far more easy to trap safely and study in the field, and transmitter durations of 3-5 years are possible. They are observable during the day, and their sign is more obvious than that of mink. The territorial behavior of the American otter facilitates the determination of population densities and assists in monitoring efforts. They also live longer than mink, therefore, they synthesize environmental influences for a longer period. Study skins and furs up to 150 years old are available, allowing a historical analysis of metal concentrations in hair. This historical information could not be collected using mink. Literature worldwide documents anthropogenic toxins as one reason for otter populations declining in many parts of the world.

Unfinished Business

Relevancies

Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): coastal wetlands, **nearshore terrestrial**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 5: Bird or animal deformities or reproductive problems

Last Revised

Feb. 24, 2000

Protected Nearshore Areas (Indicator ID: 8149)

Measure

The percentage of the Great Lakes shoreline under various levels of protection in six classes as defined by the International Union for the Conservation of Nature (IUCN). The six IUCN classes are 1) strict protection, such as nature reserves and wilderness; 2) ecosystem conservation and recreation, such as national parks; 3) conservation of natural features, such as natural monuments; 4) conservation through active management, such as wildlife management areas; 5) protected landscapes/seascapes; and 6) managed resource protected areas, such as sustainable use areas.

IUCN. 1994. Guidelines for Protected Areas Management Categories. Commission on National Parks and Protected Areas with the assistance of World Conservation Monitoring Centre. Gland, Switzerland, and Cambridge, U.K.

Purpose

To assess the kilometres/miles of shoreline in protective status. This information will be used to infer the preservation and restoration of habitat and biodiversity, the protection of adjacent nearshore waters from physical disturbance and undesirable inputs (nutrients and toxics), and the preservation of essential habitat links in the migration (lifecycle) of birds and butterflies.

Ecosystem Objective

The Great Lakes shall be free of… net loss of fish and wildlife habitat (GLWQA, Annex 2, item xiv). Also relates to several of Lake Superior LaMP's Habitat Objectives including: land and water uses should be designed and located in harmony with the protective and productive ecosystem functions; degraded features should be rehabilitated or restored; and, land use planning and regulation should eliminate or avoid destructive land-water linkages, and foster healthy land-water linkage.

Endpoint

Significant increase in extent of Great Lakes shoreline within formal protected areas.

Features

The reference values are the kilometres/miles of shoreline which are protected as a percent of the total shoreline and the percent of increase or decrease over time as measured every two to four years.

Illustration

For each selected area (e.g., basin-wide, lake, special shoreline community, ecoregion, etc.) graphs will be displayed with the percentage of protected area on the y axis and years on the x axis. Additionally, for each selected area, maps will be displayed that show the protected shoreline and its class of protection.

Limitations

Data on national parks and RAMSAR sites should be relatively easy to obtain. However, data from other locations require the cooperation of state/provincial and local authorities, who may not always have the resources to collect or maintain this information. If baseline data is not readily available, collecting the data will be resource-intensive, and therefore expensive. Subsequent data updates will require only moderate expense. This indicator is useless unless the data inventory is kept up to date and there is consistency in data treatment (database management and GIS) which will require readily available expertise, a continuing, low-level, effort in data management, and a consistent approach.

Interpretation

Once the baseline is established, the percent of the shoreline in protected status can be tracked. “Bad” or “good” trends will be determined by how the percent of the shoreline in protected status is changing over time. An increase in the percent of shoreline in protected status would be considered “good;” a decrease would be considered “bad.” The indicator may be complemented by information on the status (ecological integrity, quality) of wetlands, natural land cover along the shoreline, and information on special communities. It may be interesting to show where protected areas and AOC/RAP or Biodiversity Investment Areas coincide, and where the information for this indicator is useful for the evaluation of RAPs or Biodiversity Investment Areas.

Comments

A protected area database has been kept at Environment Canada; whether it is up-to-date or not is unknown. Precise spatial information (precise location and extent, which part of the shoreline, how far inshore) is either not available or poor. In Canada, data for RAMSAR sites, national parks, or MAB sites should be easy to locate. It is not known how often this data is updated, or whether the sites are periodically monitored for their quality (ecological integrity). In the U.S., data on protected areas would have to be compiled from federal and state agency sources. A useful starting point for relevant data can by found in the Environmental Sensitivity Atlases for each of the lakes and connecting channels.

This indicator overlaps with coastal wetland indicators. It would be good to link the information with an indicator on the location, extent and quality of wetlands; also, to what extent these wetlands are protected. The indicator may need some refinement to express "representativeness" (proportion of special lakeshore habitat types included) or better links to "Important Bird Areas", or conservation plans.

MAB	Man and the Biosphere. Initiated by UNESCO to address problems relating to conservation of resources, resources systems, and human settlement development.
RAMSAR	The Convention on Wetlands, signed in Ramsar, Iran in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.
UNESCO	United Nations Educational, Scientific and Cultural Organization

Unfinished Business

Relevancies
Indicator Type: human activity
Environmental Compartment(s): land
Related Issue(s): habitat, stewardship
SOLEC Grouping(s): **nearshore terrestrial**, societal
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 24, 2000

Urban Density (Indicator ID: 7000)

Measure
Human population per square kilometre of existing and proposed development areas. Total area is adjusted to exclude parks and other designated greenspace.

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
Socio-economic viability and sustainable development are generally accepted goals for society.

Endpoint
The most efficient and ecologically sustainable conditions will occur when large urban centres are intensively developed with a high population density. The contrary exists for sparsely populated rural areas — the lower the population density the less stress is imposed on the ecosystem. As a corollary, new growth is best accommodated by adding to the high density area rather than the lower density rural areas.

Features
Urban density is a relative measure of efficiency. In general, and other things being equal, higher density land use is less energy and resource consuming and thus is more efficient from an ecosystem perspective. For example, transportation in higher density areas is less resource demanding since distances are shorter and public transportation is often more available and inexpensive. Consequently, air pollution should be lower in more densely populated areas. In addition, since inefficient land use for urban development implies loss of land use for natural and other purposes there are significant biodiversity dimensions to inefficient land use. In general, the less land used for development, the greater the opportunities that exist for natural biodiversity goals to be met. Urban densities have been declining over time as urban development has become much more sprawling with the vast majority of new development occurring on former agricultural or natural lands. This has resulted in greater reliance for urban residents on the automobile as virtually the only method of public transit for these widespread and low density new communities has become impractical. Information for this indicator needs to be collected perhaps every 5 or 10 years as changes in density take place relatively slowly.

Illustration
This indicator will be displayed by a numerical ratio of population to land area (population per square kilometre).

Limitations
This indicator is useful in comparing municipalities to each other, but would need to be aggregated into an index in order to be represented as a basin wide measure. Identifying park space may be complicated and difficult in some cases because the information most likely exists only at the local level and would require a survey to collect.

Interpretation
The indicator is a simple representation of urban efficiency since higher density communities typically are lower in cost and less intrusive on the rest of the ecosystem. Thus, the higher the ratio of population per square kilometre of land the better in achieving overall urban efficiency and a less stressed ecosystem.

Comments
The indicator is also a good proxy for commercial and industrial sprawl since development patterns for this sector typically parallels that of residential development. The socio-economic paper of SOLEC '94 indicated the relative urban densities between the City of Toronto, Ontario and Chicago, Illinois. The SOLEC '96 Land Use paper also discussed at length the efficiency aspects of higher density through the report.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): land
Related Issue(s):
SOLEC Grouping(s): **land use**
GLWQA Annex(es):
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Land Conversion (Indicator ID: 7002)

Measure
Percent change in land use type, including agriculture, urban development, and forest, marsh or other natural cover.

Purpose
To assess the changes in land use within the Great Lakes basin, and to infer the potential impact of land conversion on Great Lakes ecosystem health.

Ecosystem Objective
Sustainable development is a generally accepted land use goal for Canadians and Americans. This indicator supports Annex 13 of the GLWQA.

Endpoint
Zero change would be sustainable but probably unrealistic, while reversion of other uses to the natural ecosystem would be desirable.

Features
High rates of land conversion place stress on the natural ecosystem and are typically associated with inefficient land use, such as urban sprawl. Population growth is a driver for more development which displaces both agricultural and natural lands. Other things being constant, high conversion rates are associated with rapid rates of urban sprawl which is economically inefficient and displaces natural land that serves other biological purposes in the ecosystem or agriculture which in turn may convert land from natural uses. The conventional pattern of land conversion has been for urban growth to displace agricultural lands which, in turn, expand into remaining lands. Urban development also expands into natural lands.

Illustration
The indicator allows easy and visual interpretation of land use changes and trends. Land conversion is an evolutionary process and this indicator will be displayed as a graphical representation of land use by category in the basin.

Limitations
This indicator provides a measurement of the conversion of the land use type, but not of the change in quality of the land use. For example, conversion of a highly intensive, chemical-intensive agriculture area to an urban area, particularly one that is well-planned and utilizes environmental and resource conservation management plans, may result in less stress to the ecosystem. Also, urban development on excavated, landfill or other contaminated sites may also be positive changes.

Interpretation
Generally, land that converts from natural to agricultural and from natural and agricultural uses to developed uses is undesirable. Conversion back to natural uses would be desirable.

Comments
SOLEC '96 represented the rate of land converted from agriculture to developed urban uses. Clearly, loss of agricultural land in the basin places pressure on other lands such as forests and wetlands to be placed into agricultural uses. Satellite imagery might be useful in detailing the changes over time of the urban frontier actually developed and this indicator.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): land
Related Issue(s):
SOLEC Grouping(s): **land use**
GLWQA Annex(es): 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Brownfield Redevelopment (Indicator ID: 7006)

Measure
Total acreage of redeveloped brownfields.

Purpose
To assess the acreage of redeveloped brownfields, and to evaluate over time the rate at which society rehabilitates and reuse former developed land sites that have been degraded by poor use.

Ecosystem Objective
Sustainable development is a generally accepted goal for North American society.

Endpoint
Elimination of all brownfield sites.

Features
"Brownfields" are abandoned, idled, or under-used industrial and commercial facilities where expansion, redevelopment, or reuse is complicated by real or perceived environmental contamination. Some of the sites contain underground storage tanks; others have contaminated soils from industrial waste or manufacturing byproducts. Still others may possess no contamination at all, but the fear of contamination nonetheless scares prospective buyers and lenders away. This creates an incentive for development to occur in pristine, undeveloped areas.

The indicator would describe trends in brownfields redevelopment and urban renewal, including areas that technically can not be described as brownfields. The indicator is a measure of the rate at which society is employing former contaminated (typically industrial) sites to new and more environmentally compatible uses. Brownfields reuse offers an opportunity to reduce pressure on the ecosystem by slowing the rate of land conversion and typically increasing urban densities. An inventory of contaminated sites is maintained by most provincial and state and federal governments, although a broader definition would require municipal involvement. The goal is to redeploy all of these lands as soon as possible.

Illustration
The total number of identified acres of outstanding brownfield sites throughout the basin by state/province and lake basin. Bar graphs could be used to demonstrate changes over time.

Limitations
The identification of brownfield sites is limited by the availability of information on vacant and redeveloped sites. Data for this indicator may not reveal an accurate trend in brownfield redevelopment, particularly if redevelopment on brownfield sites results in another use that causes further land contamination.

Interpretation
Reducing the number of acres/square kilometres of brownfield sites can be seen as a positive development in the basin. Increasing brownfield inventories not only indicate challenges of dealing with contaminated sites but also opportunities for redevelopment.

Comments
Numerous examples are available including one site in Detroit that has been converted to a public park. Others are typically reduced as urban housing or clean industrial use.

The achievement of the end point will depend on the opportunities available for new land uses as an alternative to land conversion.

Unfinished Business

Relevancies
Indicator Type: human activity
Environmental Compartment(s): land
Related Issue(s): stewardship
SOLEC Grouping(s): **land use**
GLWQA Annex(es):
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Mass Transportation (Indicator ID: 7012)

Measure
Percent of commuters using public transportation.

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

Ecosystem Objective
Sustainable development as interpreted by Canada and the U.S. through ongoing efforts of agencies, such as the Canadian National Roundtable on Environment and Economy, and more specifically pollution related as recognized in Annex 15 of the GLWQA.

Endpoint
A ratio over 50% would be desirable.

Features
The indicator is a simple measure of the average number of commuters using public (mass) transit in urban centres throughout the basin. It is valuable in recognizing the socio-economic costs associated with urban form that contributes to highly energy intensive, highly polluting, non-productive and time wasting urban commuting. The indicator could be aggregated and used as a basin wide indicator. Data are typically collected by survey and may vary from community to community and with respect to periodicity.

Illustration
The indicator is represented graphically by a ratio of daily working commuters that use public transit options including rail and road mass transit options.

Limitations
The indicator is a proxy for efficiency of an urban community. It focuses only on work commuters as data is not available for other commuting purposes, such as recreation. Finally, not all public transit may be more efficient than the use of private automobiles, for example, empty buses running on low density suburban streets.

Interpretation
Use of public transit for commuting in urban communities is typically more efficient than the private automobile. Less energy is required, less pollution created, more land can be dedicated to living/working space and less to unproductive roads and parking lots, less working and non-working time is wasted behind the wheel of a car, and the costs to the community are reduced by higher levels of urban transit use.

Comments
Reducing the amount of time and the cost of travelling for work and pleasure will impact on total resource use in society as well as reducing the amount of unproductive time spent commuting to work and increasing recreational time. Greater adoption of mass transportation involves changes in urban development patterns as well as lifestyle. The former City of Toronto, with a relatively dense and compact urban form had a relatively high level of mass transportation. That level fell considerably when the City expanded its municipal boundaries to include more suburban areas.

Private vehicle commuter traffic is responsible for a significant amount of current smog in cities and is a major contributor to global climate change through the emission of large quantities of greenhouse gases derived from non-renewable sources.

This is only a proxy measure of the efficiency of goods transportation.

Unfinished Business
< Need to determine the time-scale of indicator. For example, will the measurements provided for this indicator be taken on an annual basis? A biennial basis?...

< Need to determine how the indicator will be presented? For example, this indicator could show trends in use of mass transit over time using a bar graph with percentage of commuters using public transportation on the y axis and years on the x axis.

< Need to add a discussion related to understanding the trends presented by the indicator. For example, what baseline will be used to determine if 50 percent of commuters are using public transportation?

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, land
Related Issue(s): climate change, stewardship
SOLEC Grouping(s): **land use**
GLWQA Annex(es): 11: Surveillance and monitoring, 15: Airborne toxic substances
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Sustainable Agricultural Practices (Indicator ID: 7028)

Measure
Number of Environmental and Conservation farm plans in place.

Purpose
To assess the number of Environmental and Conservation farm plans, and to infer environmentally friendly practices in place, such as integrated pest management to reduce the unnecessary use of pesticides, zero tillage and other soil preservation practices to reduce energy consumption, and prevention of ground and surface water contamination.

Ecosystem Objective
This indicator supports Annexes 2, 3, 12 and 13 of the GLWQA.

Endpoint
Sustainable agriculture through non-polluting, energy efficient technology and best management practices for efficient and high quality food production.

Features
Given the key role of agriculture in the Great Lakes ecosystem, it is important to track changes in agricultural practices that can lead to better ecological integrity in the basin. The indicator identifies the degree to which agriculture is becoming more sustainable and has less potential to adversely impact the Great Lakes ecosystem. Integrated pest management and zero till soil management are typically part of an environmental farm management plan. It is expected that more farmers will embrace environmental planning over time.

Illustration
The total number of farm environmental plans (or ecological plans) that are in place as a percentage of the total number of farms in the basin.

Limitations
Plans vary from jurisdiction to jurisdiction and thus may lack consistency in terms of completeness of agricultural sustainable practices. In addition there is no standard way of knowing the state of implementation of these plans.

Interpretation
Having an environmental management plan in place provides an incentive for farmers to commit to environmentally sound land use practices. The more plans in place the better. In future there may be a way to grade plans by impacts on the ecosystem. The first year in which this information is collected will serve as the base line year.

Comments

Unfinished Business
< This indicator requires much further development and refinement. Specific consideration will be given to assessing the use of conservation tillage, buffer strips and herbicide application.

Relevancies
Indicator Type: human activity
Environmental Compartment(s): land
Related Issue(s): stewardship
SOLEC Grouping(s): **land use**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 3: Control of phosphorus, 11: Surveillance and monitoring, 12: Persistent toxic substances, 13: Pollution from non-point sources
IJC Desired Outcome(s): 8: Absence of excess phosphorus, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 8: Eutrophication or undesirable algae, 14: Loss of fish and wildlife habitat

Last Revised
Feb. 24, 2000

Green Planning Process (Indicator ID: 7053)

Measure
Number of municipalities with environmental and resource conservation management plans.

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.

Ecosystem Objective
Sustainable development is a goal of North American society. This indicator supports Annex 13 of the GLWQA.

Endpoint
All municipalities should have an environmental and resource conservation plan.

Features
The indicator is an acknowledgment that municipalities with environmental and resource conservation management plans require resource conservation as a mandatory part of the municipal land use decision process. Ideally all municipalities in the basin will focus on limiting urban sprawl; incorporating a preference for high density, redevelopment and brownfield utilization; conserving of natural features and resources, such as natural watercourse retention and woodlot preservation; and promoting mass transit. Once a development plan (i.e., a plan submitted by developers for new development) has been approved, it is safe to assume that it has taken account of environmental considerations.

Illustration
The indicator will be a numerical ratio of municipalities that do have plans out of the total number of municipalities in the basin. This could be presented by maps or through simple numerical ratios.

Limitations
This indicator will provide a measurement of the number of green plans in place, but will not assess the quality of the plans or if they are being implemented.

Interpretation
An increasing number of plans over time represent a positive trend. The indicator will be used to determine improvements over time as more municipalities undertake to develop and implement these plans. Data collected during the first year will serve as a baseline.

Comments
Oakland County Michigan has a detailed provision that all developers must follow in order to develop their lands.

Unfinished Business

Relevancies
Indicator Type: human activity
Environmental Compartment(s): water, land
Related Issue(s): stewardship
SOLEC Grouping(s): **land use**, societal
GLWQA Annex(es): 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

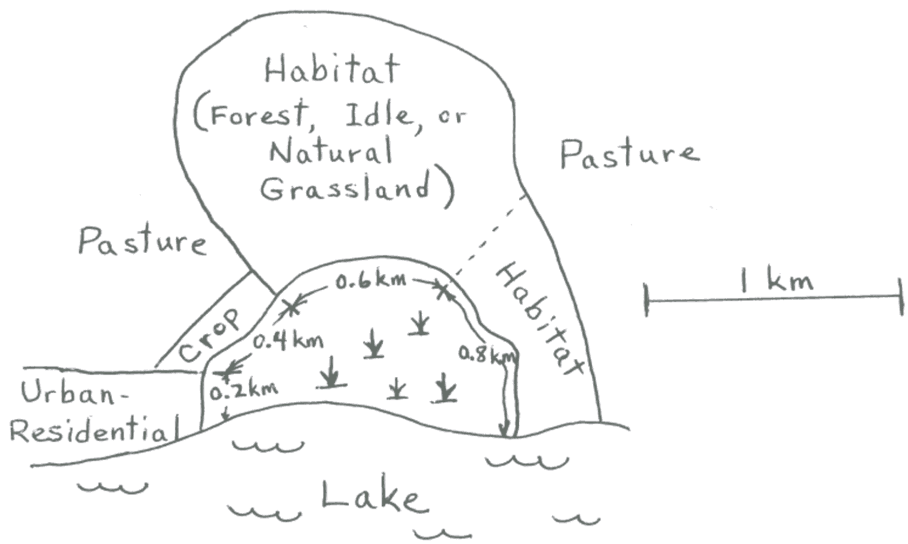
Last Revised
Feb. 24, 2000

Habitat Adjacent to Coastal Wetlands (Indicator ID: 7055)

Measure

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

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



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

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

Purpose

To provide an index of the quality of adjoining upland habitat which can have a major effect on wetland biota, many of which require upland habitat for part of their life cycle.

Ecosystem Objective

To maintain and restore healthy coastal wetlands and associated diverse wildlife populations which require adequate adjoining upland habitat (GLWQA Annexes 2 and 13).

Endpoint

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

Features

This is an indicator of off-site influence, and assesses the effects of land uses adjacent to coastal wetlands. It is potentially linked to all of the Coastal Wetland State/Response indicators. Although related to indicator 8132, Nearshore Land Use, and to indicator

8136, Nearshore Natural Land Cover, its specificity to wetlands makes it much more relevant to wetland health. It will show steady trends rather than high variability.

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

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

Interpretation
The lower the weighted average, the worse the ranking.

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

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

Unfinished Business

Sorting
Indicator Type: state
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): coastal wetlands, nearshore terrestrial, **land use**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 9: Physical environment integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 24, 2000

Habitat Fragmentation (Indicator ID: 8114)

Measure
The pattern of natural habitat remaining within ecoregions/subsections, as measured by 1) area to perimeter ratio; 2) habitat patch size; and 3) percent intact cover.

Purpose
To assess the amount and distribution of natural habitat remaining within Great Lakes ecoregions, and to infer the effect of human land uses such as housing, agriculture, flood control, and recreation on habitat needed to support fish and wildlife species.

Ecosystem Objective
Each LaMP is likely to contain objectives that address maximizing the amount of land cover adjacent to the lake. This indicator supports Annex 2 of the GLWQA.

Endpoint
The Framework on Guiding Habitat Rehabilitation in Great Lakes Areas of Concern (Environment Canada et al, 1998) suggests specific marsh and forest patch sizes that are required to support various species. For example, 200 hectares of forest patch is required for successful interior forest bird breeding. A total area with more than 70% intact cover is needed for birds.

Features
This indicator will present trends in remaining natural habitat within ecoregions/subsections over time. Sufficient parcels of natural habitat are necessary to support wildlife activities such as breeding and migration. For example, lack of interior forest habitat adversely impacts the reproduction of breeding birds. Loss of natural habitat also adversely impacts migrating birds that need to touch down to refuel on their treks north and south. For some threatened species, there is insufficient habitat to sustain populations.

Illustration
Using GIS, habitat patch size and percent intact cover can be graphically displayed on a map. Calculations to determine area to perimeter ratio could be done on a GIS using a specially designed algorithm. Although illustrating area to perimeter ratio is more difficult, it would be possible to highlight all patches with a desirable ratio on a GIS map once calculations are complete.

Limitations
Although “intact cover” most likely means natural vegetation, primarily forest, there is a need to define this term. The relationship, for example, between the three endpoints — percent intact cover, patch size and perimeter to area ratio — and bird breeding is better understood than the relationship between the endpoints and bird migration. A better understanding of how these endpoints affect bird migration is necessary.

Interpretation
Additional research is needed to understand how much habitat is required in a particular ecoregion for different species and for different functions.

Comments
As suggested, the amount of habitat required for breeding birds is known, but less is known about the amount of natural vegetation required for migrating birds. The requirements for other species will be just as challenging. Information for this indicator can be collected using remote sensing products.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): land
Related Issue(s): habitat
SOLEC Grouping(s): **land use**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

Last Revised
Feb. 24, 2000

Contaminants in Recreational Fish (Indicator ID: 113)

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

Purpose
This indicator will assess the levels of PBT chemicals in fish, and it will be used to infer the potential harm to human health through consumption of contaminated fish.

Ecosystem Objective
Fish should be safe to eat. This indicator supports Annexes 1, 2 and 12 of the GLWQA.

Endpoint

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

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

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

Interpretation

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

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

Relevancies
Indicator Type: pressure
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): open waters, nearshore waters, **human health**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 1: Fishability, 4: Healthy human populations, 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 1: Restrictions on fish and wildlife consumption

Last Revised
Feb. 24, 2000

E. coli and Fecal Coliform Levels in Nearshore Recreational Waters (Indicator ID: 4081)

Measure
1) Counts of *E. coli* and/or fecal coliforms (FC) in recreational waters measured as number of organisms per volume of water (e.g., FC/ml); and 2) frequency of beach closings at specific locations.

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

Ecosystem Objective
Waters should be safe for recreational use. Waters used for recreational activities involving body contact should be substantially free from pathogens, including bacteria, parasites, and viruses, that may harm human health. This indicator supports Annexes 1, 2 and 13 of the GLWQA.

Endpoint
E. coli and fecal coliform levels should not exceed national, state, and/or provincial standards set for recreational waters.

Features
One of the most important factors in nearshore recreational water quality is that it be free from microbial contamination. Recreational waters may become contaminated with animal and human feces from sources and conditions such as combined sewer overflows that occur in certain areas after heavy rains, agricultural run-off, and poorly treated sewage. This indicator will track *E. coli* and fecal coliform abundance and the frequency of beach closings over time and across geographic locations throughout the basin. Analysis of data may show seasonal and local trends in nearshore recreational waters. The trends provided by this indicator will aid in beach management and in the prediction of episodes of poor water quality.

Illustration
For each site selected throughout the basin, a bar graph will be presented showing the counts of *E. coli* and fecal coliform over several years. Statistical analysis will be used to examine the temporal and spatial trends in water quality in recreational beach areas. Data will be presented as a bar graph or as a GIS map showing the number of beach closings over time.

Limitations
Variability in the data from year to year may result from the process of monitoring and variations in reporting, and may not be solely attributable to actual increases or decreases in levels of microbial contaminants. In addition, variability of weather from year to year may also affect the variability in bacterial counts. Viruses and parasites, although a concern in recreational waters, are difficult to isolate and quantify at present, and feasible measurement techniques have yet to be developed. Comparisons of the frequency of beach closings will be limited due to use of different water quality criteria in different localities.

Interpretation
This indicator will rely on national, state, and/or provincial *E. coli* or fecal coliform standards as a benchmark. Trends that demonstrate an increase in fecal pollution levels over time, and above the appropriate standard, will be considered negative, or bad, trends. Trends that demonstrate a decrease in fecal pollution levels over time, and below the appropriate standard, will be considered positive, or good, trends.

Comments
Analysis of data may show seasonal and local trends in recreational water. If episodes of poor recreational water quality can be associated with specific events, then forecasting for episodes of poor water quality may become more accurate.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water, biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): nearshore waters, **human health**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources
IJC Desired Outcome(s): 2: Swimmability, 4: Healthy human populations
GLFC Objective(s):
Beneficial Use Impairment(s): 10: Recreational water impairment

Last Revised
Feb. 24, 2000

Contaminants in Edible Fish Tissue (Indicator ID: 4083)

Measure
Concentration of PBT chemicals targeted by the GLWQA in edible fish tissue.

Purpose
To assess the concentration of persistent, bioaccumulating, toxic (PBT) chemicals in Great Lakes fish, and to infer the potential exposure of humans to PBT chemicals through consumption of Great Lakes fish caught via sport and subsistence fishing.

Ecosystem Objective
Fish in the Great Lakes ecosystem should be safe to eat; consumption should not be limited by contaminants of human origin. This indicator supports Annexes 1, 2 and 12 of the GLWQA.

Endpoint
Reduction in concentration of PBT chemicals in fish tissue to levels that do not pose a risk to populations consuming Great Lakes fish. The elimination of fish advisories in the Great Lakes may be considered to be an appropriate endpoint.

Features
The temporal and geographic trends in the chemical contaminant levels in fish species consumed by human populations in the Great Lakes basin will be used as an indicator of exposure to PBT chemicals. Concentrations of contaminants in fish should be determined from a boneless, skinless fillet of dorsal muscle flesh removed from the fish. This would provide not only the most consistent test results, but is also the most edible portion of the fish. Choosing appropriate indicator species is crucial and should be based on fish consumption patterns and availability of data. Additional chemicals can be considered as new information arises. The indicator will allow regulatory agencies to make suggestions regarding remedial planning as well as issuing advisories to the public on safe consumption limits.

Illustration
Results of raw data will be used to construct simple bar graphs showing the fluctuation of contaminants over time and space.

Limitations
Data for use in developing indicators exist, however, there are differences in surveillance techniques for fish consumption and differences in tissue sampling methods between jurisdictions.

Interpretation
Reductions in contaminant levels in fish tissue will reflect an improvement in environmental quality and the potential for reduced exposure to contaminants from consumption of Great Lakes fish.

Comments

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): fish
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): open waters, nearshore waters, **human health**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 1: Fishability, 4: Healthy human populations, 6: Biological community integrity and diversity, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior
Beneficial Use Impairment(s): 1: Restrictions on fish and wildlife consumption

Last Revised
Feb. 24, 2000

Chemical Contaminant Intake from Air, Water, Soil and Food
(Indicator ID: 4088)

Measure
Estimated total daily intake of PBT chemicals targeted by the GLWQA from air, water, soil, and food sources.

Purpose
To estimate the daily intake of PBT chemicals from all sources, and to evaluate the potential harm to human health and the efficacy of policies and technology intended to reduce PBT chemicals.

Ecosystem Objective
This indicator supports Annex 12 of the GLWQA.

Endpoint
Intake of PBT chemicals from all sources should be below established guideline values and should continue to decline.

Features
This indicator tracks contaminants levels in various media and their estimated daily intake via ingestion and inhalation. Daily intakes have been estimated for the following age groups : 0 - 0.5 years, 0.5 - 4 years, 5 - 11 years, 12 - 19 years, 20 + years, and total lifetime, using available data up to 1996 (Great Lakes Health Effects Program, Health Canada). Estimated daily intakes can be updated periodically, as new data becomes available.

Illustration
The temporal variation in estimated dose for each age group and the relative contribution of each media as a percentage of total dose will be displayed in a graphic format.

Limitations
Factors such as technological advances, differences in sampling and laboratory procedures, as well as survey questionnaires, create difficulties in accurately comparing historical data.

Interpretation
Changes in the estimated daily dose from air, water, soil or food sources will indicate changes in environmental quality, in human exposure, and the risk to human health.

Comments

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): humans
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **human health**
GLWQA Annex(es): 11: Surveillance and monitoring, 12: Persistent toxic substances
IJC Desired Outcome(s): 4: Healthy human populations, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Drinking Water Quality (Indicator ID: 4175)

Measure
Concentrations of chemical substances such as metals (e.g., lead, mercury) and other inorganic compounds, pesticides, radionuclides, and drinking water disinfection by-products (e.g., trihalomethanes) as well as microbial parameters such as bacteria, viruses and parasites in raw, treated and distributed drinking water.

Purpose
To assess the chemical and microbial contaminant levels in drinking water, 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
Treated drinking water supplies should be safe to drink. This indicator supports Annexes 1, 2, 12 and 16 of the GLWQA.

Endpoint
Densities of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances should not exceed human health objectives, standards, or guidelines.

Features
This indicator would reveal trends in contaminant levels in raw, treated and distributed water in various locations throughout the basin. Through existing water monitoring programs, which analyse raw, treated and distributed waters, results can be compared against established water quality objectives. This evaluation applies to water supply systems that draw water from either surface water or groundwater sources. Data on temporal trends, such as seasonal differences or changes over time, in chemical or microbial contaminant concentrations for specific locations could be identified.

Illustration
For selected locations in the Great Lakes basin, simple bar or line graphs would display the average concentration of contaminants in raw, treated and distributed water. The data could also be displayed in a GIS format that would allow for a variety of endpoint analyses to be displayed as an overlay on maps of the entire Great Lakes basin or more local areas.

Limitations
Most contaminants in drinking water rarely exceed guidelines and many are below their analytical detection limit. Since the absolute concentration of some contaminants may not be determinable, it is difficult to show fluctuations in their concentration levels.

Interpretation
Existing monitoring programs at drinking water treatment plants analyze for chemical and microbial contaminants in raw, treated and distributed waters. Results can be compared against established water quality guidelines and objectives. The data could be supplemented with additional information showing relationships between contaminant levels and human health risks; for example, the association between long-term exposure to chlorination disinfection by-products in drinking water and the increased risk of bladder and colon cancers.

Comments

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): contaminants & pathogens, nutrients
SOLEC Grouping(s): open waters, nearshore waters, **human health**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 12: Persistent toxic substances, 16: Pollution from contaminated groundwater
IJC Desired Outcome(s): 3: Drinkability, 4: Healthy human populations
GLFC Objective(s):
Beneficial Use Impairment(s): 9: Restrictions on drinking water consumption or taste and odor problems

Last Revised
Feb. 24, 2000

Air Quality (Indicator ID: 4176)

Measure
Concentration of chemicals and particulate matter in ambient air.

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. This is consistent with ecosystem objectives statements being adopted by certain lakewide management plans, including Lake Superior, (Ecosystem Principles and Objectives, Indicators and Targets for Lake Superior, Lake Superior Binational Program, 1995), in fulfilment of Annex 2 of the Great Lakes Water Quality Agreement. This indicator also supports Annexes 1, 13 and 15.

Endpoint
Canadian and U.S. air quality standards.

Features
The Great Lakes basin experiences high levels of certain air pollutants due to both local sources and long range transport. Studies conducted in the Great Lakes region have provided strong evidence linking ground-level ozone and sulphates to increased rates of hospital admissions for cardiorespiratory disease and to increased death rates. Pollutants that can be used to assess overall air quality include SO_2, CO, O_3, NO_x, TRS and SP. Air toxics, such as benzene, formaldehyde, and ethylene dichloride, should also be used to assess air quality. Other air pollutants can be added as new information becomes available. This indicator can use information from existing air monitoring databases. Data can be supplemented with established associations between levels of ambient air pollution and rates of admissions to acute care hospitals for cardiorespiratory disease.

Illustration
Using a GIS mapping display, trends in pollutant levels over several years for each pollutant in a particular region or over the entire Great Lakes basin data could be presented. Data could also be displayed as the number of exceedances of guidelines which may be established for any pollutant. The above data could be supplemented with additional graphs showing the relationships between sulphate and ozone levels in outdoor air and hospital admissions for cardiorespiratory diseases.

Limitations
Canadian and U.S. jurisdictions employ different standards for measurement of exceedances.

Although indoor air is a major contributor to exposure to air toxics, there is no practical way to consistently monitor indoor air quality. Therefore, this component to the estimate of total exposure to airborne contaminants will not be included in this indicator.

Interpretation
Interpretation of the indicator would be made by identifying trends in the levels of air contaminants over time in comparison to guideline levels.

Comments
A significant association is found between atmospheric ozone and sulphate levels and the number of daily hospital admissions for respiratory conditions. Five percent of daily respiratory admissions in the months of May to August can be attributed to ozone, and an additional 1% to sulphates. This finding is consistent among all age groups. The largest impact appears to be on children under 2 years of age, in whom 15% of respiratory hospital admissions are attributed to ozone and sulphate together, while the elderly are least affected (4%). There does not appear to be a level of ozone below which no adverse respiratory health effects are observed.

For both respiratory and cardiac illnesses, the average daily hospitalization rates increase with increasing levels of sulphates. A 13 ug/m^3 increase in sulphates recorded on the previous day is associated with a 3.7% increase in respiratory admissions and a 2.8% increase in cardiac admissions. Admissions for cardiac diseases increases 2.5% for those under 65 years and 3.5% for those 65 years and older.

Some air pollution emissions can be prevented through better pollution prevention or by changing the demand for certain products and services that contribute to air pollution. Therefore, this indicator can additionally measure progress on sustainable development by determining the degree to which resources are wasted as pollution, thereby representing inefficiency in human economic activity.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **human health**
GLWQA Annex(es): 1: Specific objectives, 2: Remedial Action Plans, 11: Surveillance and monitoring, 13: Pollution from non-point sources, 15: Airborne toxic substances
IJC Desired Outcome(s): 4: Healthy human populations
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Chemical Contaminants in Human Tissue (Indicator ID: 4177)

Measure
Concentrations of PBT chemicals targeted by the GLWQA in human tissues such as blood, breast milk, hair, urine and adipose tissues.

Purpose
To assess the concentration of PBT chemicals in human tissues, and to infer the efficacy of policies and technology to reduce PBT chemicals in the Great Lakes ecosystem.

Ecosystem Objective
This indicator supports Annexes 1, 12 and 17 of the GLWQA.

Endpoint
Continued reduction of PBT chemical concentrations in human tissue. Where PBT chemicals are detected, they should be maintained below health guidance levels.

Features
This indicator will monitor the concentration of PBT chemicals in human tissues (both general and at-risk populations) to establish geographic patterns and trends over time, providing an estimate of both past and current chemical exposures.

Illustration
Data will be displayed as bar graphs showing PBT chemical concentrations over time to highlight trends and in GIS format to illustrate geographic patterns in body burden levels.

Limitations
This indicator requires extensive sampling of human populations, as well as standardized tissue collection and chemical analysis methods for use by participating laboratories. A detailed history of the sample population, including diet, lifestyle, and occupation, is necessary to characterize the history of exposure.

Interpretation
The long persistence of PBT chemicals in the body would indicate that there is a relatively long time period between reductions in exposure and subsequent reductions in tissue levels. However, trends that demonstrate a decrease in the concentration of PBT chemicals in human tissue, to levels below health guidance levels, would be a positive indication that the human health risks posed by exposure to environmental contaminants are being reduced. Tissue levels above health guidance values are a concern for human health.

Comments
The body burdens of some PBT chemicals in at-risk populations around the Great Lakes and St. Lawrence basins can be 2 to 4 times greater than the general population.

Ref. Johnson et al., 1998. Public Health Implications of Persistent Toxic Substances in the Great Lakes and St. Lawrence Basins. J. Great Lakes Res. 24(2):698-722.

Health Canada, 1998. Health-Related Indicators for the Great Lakes Basin Population: Numbers 1 to 20. Minister of Public Works and Government Services Canada.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): humans
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **human health**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 12: Persistent toxic substances, 17: Research and development
IJC Desired Outcome(s): 4: Healthy human populations, 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 15, 2000

Radionuclides (Indicator ID: 4178)

Measure
Concentration of Cs-137 and Sr-90 in cow's milk, gross beta activity in air and precipitation, and airborne and waterborne radionuclide emissions from nuclear power plants in the Great Lakes basin.

Purpose
To assess the concentrations of artificial radionuclides in cow's milk, surface water, drinking water, and air, and to estimate the potential for human exposure to artificial radionuclides.

Ecosystem Objective
This indicator supports Annexes 1 and 17 of the GLWQA.

Endpoint
Limit releases of artificial radionuclides to minimize human exposure.

Features
This indicator will provide a measure of the overall exposure of the Great Lakes basin population from nuclear weapons fallout. It will present almost 30 years of data on the concentration of cesium-137 and strontium-90, two types of radionuclides associated with above ground nuclear weapons testing, in cow's milk and gross beta activity in air and precipitation since cessation of atmospheric weapons testing. This indicator will also present trends in the concentrations of airborne and waterborne tritium, strontium-90, iodine-131, cesium-134, and cesium-137 emissions from nuclear power plants in the Great Lakes basin, providing an estimate of exposure to contaminants from nuclear power plant discharges. Measurements of radionuclide emissions may allow for the estimation of human exposure to discharges by nuclear power plants and may indicate geographical differences in exposure from those sources. In addition to natural background radiation, the Great Lakes basin contains nearly all components of the nuclear fuel cycle, as well as many radioisotope users such as hospitals and industry.

Illustration
Graphs will display almost 30 years of data on the concentration of cesium-137 and strontium-90 in cow's milk and gross beta activity in air and precipitation. Graphs will also present reported airborne and waterborne tritium, strontium-90, iodine-131, cesium-134, and cesium-137 emissions from nuclear power plants in the Great Lakes basin, beginning in 1972 (IJC Nuclear Task Force, 1997).

Limitations
Monitoring of radionuclides in the Great Lakes basin meets primarily the compliance needs of licenses for discharge. Very little of the current monitoring activities are designed to address, or are capable of considering, the movement and cycling of radionuclides through environmental compartments and ecosystems. The data for Cs-137 and Sr-90 concentrations collected during the past 30 years show a decline in radioactivity in the Great Lakes basin after the ban on above ground nuclear weapons testing. The trend illustrated by these data — decreased exposure to Cs-137 and Sr-90 due to decreased weapons testing — is not especially useful to policy makers and regulatory agencies.

Interpretation
A trend of decreasing concentration of artificial radionuclides over time would indicate a reduction in risk to human health. A trend of increasing concentrations would indicate a potential for greater human exposure.

Comments
Hypothetical estimates based on conservative exposure models estimates the total number of fatal cancers, non-fatal weighted cancers, and hereditary disorders over the lifetime of the current Canadian Great Lakes basin population attributable to a 50-year exposure to natural background radiation is of the order of 340,000. The total number of health effects attributable to radioactive fallout from all the weapons tests to date would be in the order of 5,000. Health Effects due to 50 years of operation of the nuclear fuel cycle at current levels would be of the order of 200. (Health Canada, 1997). On average, natural radiation accounts for more than 98% of human exposure to ionizing radiation, excluding medical exposures.

Health Canada. 1997. State of Knowledge Report on Environmental Contaminants and Human Health in the Great Lakes Basin. Minister of Public Works and Government Services Canada, Catalogue No. H46-2/97-214E.

International Joint Commission. 1997. Inventory of Radionuclides for the Great Lakes. Nuclear Task Force.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, water, biota
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **human health**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 17: Research and development
IJC Desired Outcome(s): 4: Healthy human populations
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Geographic Patterns and Trends in Disease Incidence (Indicator ID: 4179)

Measure
Disease incidence rate (rate = number of new cases of specific disease/ size of population) for those diseases that have a demonstrated environmental link, such as cancers and birth defects, in the Great Lakes basin.

Purpose
To assess geographic and temporal patterns in disease incidences in the Great Lakes basin population, and to identify areas where further investigation of the exposure and effects of environmental pollutants on human health is needed.

Ecosystem Objective
This indicator relates to Annex 17 of the GLWQA.

Endpoint
Disease incidence rates should decrease over time. Environmental pollutants should be minimized as health risk factors.

Features
This indicator provides geographical and temporal patterns of disease incidence, such as cancer and birth defects, throughout the Great Lakes basin. Although cause and effect relationships cannot be established from this indicator, it is useful for identifying areas that may require investigation.

Illustration
This indicator is represented by maps of the Great Lakes basin illustrating the distribution of disease incidences, such as cancers and birth defects, in Ontario. In addition, a graph will show trends in the incidences of diseases over time.

Limitations
The accuracy of this indicator depends on the availability and quality of hospital records and continuing improvements of registry databases. Cause and effect relationships between environmental conditions and disease incidence rates cannot be established from this indicator. The explanation of disease incidence rates, such as cancer and birth defects, in any area requires more extensive epidemiological research to assess the relative importance of various factors, including diet, lifestyle, occupation, and exposure to environmental contaminants.

Interpretation
Although cause and effect relationships between environmental contaminants and disease cannot be established from this indicator, it is useful for identifying areas which require investigation. Additional evaluation will be required to refine the analysis to specific cancers and birth defects that are most likely to be related to environmentally related. This indicator may also allow for the development of new hypotheses regarding the role of environmental exposure in the etiology of human disease.

Comments
This indicator could be expanded in the future to include biomonitors of exposure, biomarkers of pre-disease conditions, endocrine disruption, and low birth weight.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s): humans
Related Issue(s):
SOLEC Grouping(s): **human health**
GLWQA Annex(es): 17: Research and development
IJC Desired Outcome(s): 4: Healthy human populations
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Capacities of Sustainable Landscape Partnerships (Indicator ID: 3509)

Measure
Number of partnerships; basin location and geographic coverage; budgets, FTE staff; identification of major projects and initiatives.

Purpose
To assess the organizational capacities required of local coalitions to act as full partners in ecosystem management initiatives, including the enumeration of public-private partnerships relating to the pursuit of sustainable ecosystems through environmental management, staff, and annual budgets.

Ecosystem Objective
A Sustainable Great Lakes Ecosystem.

Endpoint
Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

Features
Identification and survey of Sustainable Landscape Partnerships and a compilation of responses.

Illustration
Graphs, charts, narrative descriptions, and maps; data presented for the Great Lakes basin and cross-broken by individual Lakes; maps indicating coverage of basin(s) by stated partnership boundaries.

Limitations
Some interpretation of definitions is required to set qualifying criteria for sustainable landscape partnerships to determine the sample frame for the survey.

Interpretation
This indicator will show the coverage of the basin(s) by place-based ecosystem management initiatives and provide descriptive information of their capacities to do this work.

Comments
Local collaborative partnerships have the potential to address ecosystem issues that have proven beyond the capacities of existing resource management programs. These issues include such landscape wide objectives as habitat protection, non-point pollution, aesthetics, and recreational opportunities. Partnerships may include many actors who have not traditionally seen themselves as significant or important ecosystem managers. These potential partners may include land use and development decision makers, municipal governments, private industries, agriculture, engineering firms, universities, non-profit organizations, community foundations, and others.

Unfinished Business
< This indicator has not been reviewed or revised since SOLEC 98. A revised indicator will be presented at SOLEC 2000.

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

Last Revised
October 20, 1999

Organizational Richness of Sustainable Landscape Partnerships (Indicator ID: 3510)

Measure
The diversity of the members participating in partnerships measured on two axes: Horizontal Integration -- the diversity of local partners; and Vertical Integration -- the direct participation of federal and state/provincial actors in local partnership initiatives.

Purpose
to assess the diversity of membership and expertise included in partnerships. Horizontal integration is a description of the diversity of partnerships required to address local issues, and vertical integration is the description of federal and state/provincial involvement in place-based initiatives as full partners.

Ecosystem Objective
A Sustainable Great Lakes Ecosystem

Endpoint
Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

Features
Horizontal Integration: Measured by surveying identified partnerships as to the range and diversity of participants engaged in full partnership.
Vertical Integration: Measured by surveying identified partnerships as to the collaborative involvement of federal and state/provincial actors as full partners in local initiatives.

Illustration
Graphs, charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

Limitations
Some definition and interpretation will be required to set parameters for "full partners" and to translate the diversity of partners into a simple scalar presentation for each locality and basin.

Interpretation
The description of the base capacities of partnerships to accomplish sustainable landscape initiatives by building collaborative relations between local decision making systems, e.g., the land conversion system: lending institutions, developers, and real estate agents; the description of the extent of participation of federal and state/provincial partners to enhance and empower these local initiatives.

Comments
Ecosystem management initiatives require new constituencies that expand the traditional boundaries of resource management. In addition, Federal, state/provincial, and regional agencies have the greatest expertise and resources to support sustainable ecosystem management. Their presence as full partners in local initiatives brings their expertise and resources to the table to assist in achieving shared goals.

Unfinished Business
< This indicator has not been reviewed or revised since SOLEC 98. A revised indicator will be presented at SOLEC 2000.

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

Last Revised
October 20, 1999

Integration of Ecosystem Management Principles Across Landscapes (Indicator ID: 3511)

Measure
Simple reporting of the adoption of ecosystem management as a guiding principle in place-based resource management programs by states/provinces and regional agencies and governments and budget allocations in support of ecosystem management programs and projects.

Purpose
To describe the extent to which federal, state/provincial, and regional governments and agencies have endorsed and adopted ecosystem management guiding principals in place-based resource management programs.

Ecosystem Objective
A Sustainable Great Lakes Ecosystem

Endpoint
Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

Features
Survey of basin and lake governments to identify policies, programs, and agencies for which ecosystem management is a guiding principle and budget allocations in support of these activities.

Illustration
Graphs and charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

Limitations
Some definition and interpretation will be required to set parameters for "adoption of ecosystem management as a guiding principle."

Interpretation
The formal adoption of ecosystem management as an agency strategy combined with an description of the resources allocated for the implementation of the strategy provides a index of institutional commitment to stewardship initiatives.

Comments
Adoption of ecosystem management principles necessarily leads to the identification of interrelationships in landscape systems. An emphasis on these interrelationships requires the completion of ecological risk and functional value assessments as well as community value surveys to determine priorities pertaining to ecosystem health. This process leads to the definition of appropriate action in places.

Unfinished Business
< This indicator has not been reviewed or revised since SOLEC 98. A revised indicator will be presented at SOLEC 2000.

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

Last Revised
October 20, 1999

Integration of Sustainability Principles Across Landscapes
(Indicator ID: 3512)

Measure
Simple reporting of the adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments and budget allocations in support of sustainability initiatives and projects.

Purpose
To describe the extent to which federal, state/provincial, and regional governments and agencies have endorsed and adopted sustainability guiding principals in place-based resource management programs.

Ecosystem Objective
A Sustainable Great Lakes Ecosystem

Endpoint
Partnerships that are setting and maintaining levels of ecosystem health and integrity throughout the Great Lakes basin, thus maintaining consistent ecological functioning and ecological benefits and services to local communities and regions.

Features
Survey of basin and lake governments to identify policies, programs, and agencies that have adopted place-based sustainability as a strategic goal and allocated resources for its achievement.

Illustration
Graphs and charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

Limitations
Some definition and interpretation will be required to set parameters for "adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments."

Interpretation
The formal adoption of place-based sustainability as a strategic goal by states/provinces and regional agencies and governments combined with a description of the resources allocated for its achievement provides a index of institutional commitment to stewardship initiatives.

Comments
Adoption of place-based sustainability principles establishes the balance between economic vitality, environmental health and social well being as a fundamental goal. It also institutionalizes a long term time horizon for ecosystem management activities. Focusing sustainability on landscapes will lead to the establishment of levels of integrity and health and an acknowledgment that functioning and inter-related systems are required to maintain this health and integrity.

Unfinished Business
< This indicator has not been reviewed or revised since SOLEC 98. A revised indicator will be presented at SOLEC 2000.

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

Last Revised
October 20, 1999

Citizen/Community Place-Based Stewardship Activities (Indicator ID: 3513)

Measure
An enumeration and description of programs and projects that engage citizens in the stewardship of their landscapes / ecosystems and/or foster the ethic of stewardship; total number of identified programs, total number of participants, basin location.

Purpose
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
A Sustainable Great Lakes Ecosystem

Endpoint
Continuing programs supporting a stewardship ethic and sense of responsibility for the landscapes within which people live. The building of a sense of place and the establishment of an identity for the local landscape including an understanding of the balance of interrelationships required to maintain the quality, health, and vitality of these landscapes over time.

A critical mass of local support for partnerships responsible for setting and maintaining levels of ecosystem health and integrity in places throughout the Great Lakes basin.

Features
Identification of place-based landscape/ecosystem education programs. Identification of place-based landscape/ecosystem festivals. Identification of other place-based Landscape/Ecosystem programs which engage citizenry in stewardship activities and/or support a stewardship ethic and sense of place.

Illustration
Graphs and charts and narrative descriptions illustrating survey responses for the Great Lakes basin and cross-broken by individual Lakes.

Limitations
Some definition and interpretation will be required to set parameters for "programs and projects which engage citizens in the stewardship of their landscapes/ecosystems."

Interpretation
Measures activities that indicate citizen/community engagement and support for stewardship.

Comments
Community support for stewardship is required if governments, agencies, industry, and others are to adopt stewardship as a core value. In the case of some issues this support will be essential. For example, habitat protection will not be successfully addressed without the collaboration of local land use decision makers who have embraced the ethic of stewardship. The extent to which these local officials will actually respond to the need for habitat protection will be determined in part by the strength of the local constituency supporting stewardship as a community value.

Unfinished Business
< This indicator has not been reviewed or revised since SOLEC 98. A revised indicator will be presented at SOLEC 2000.

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

Last Revised
October 20, 1999

Aesthetics (Indicator ID: 7042)

Measure
Visible waste and refuse in communities around the basin.

Purpose
To assess the amount of waste and decay around human activities in the Great Lakes basin, and to infer the degree to which human activities are conducted in an efficient and ordered fashion consistent with ecosystem harmony and integrity.

Ecosystem Objective
GLWQA Annex 2 requirement for aesthetics - cleanliness and freedom from evidence of waste.

Endpoint
Absence of obvious waste and decay around human activities and an obvious attention to cleanliness and respect for the environment.

Features
Aesthetics is an important aspect of society. It can relate to the management of other components of the ecosystem. Examples of poor aesthetics include waste oil and scum deposits in surface waterways, excessive trash along roadsides and on city streets, and run down and crumbling buildings within cities. The indicator is measured by a survey of waste and refuse that can be ascertained by a survey of communities in the basin. To determine the condition of aesthetics around the Great Lakes basin, surveys would need to be conducted to ascertain perspectives and opinions. This indicator is linked to other stewardship indicators, especially pollution prevention.

Illustration

Limitations
This indicator can be highly subjective although there is general agreement that obvious signs of waste and decay of private and public property are unaesthetic and signs of poor ecosystem management. The components of this indicator are not currently monitored since cleanliness and order can be highly subjective. Aesthetics should be kept in the context of waste or lack of maintenance and not become a matter or issue of taste and style.

Interpretation
This indicator represents a culture of maintenance and respect of the environment. A result approaching the endpoint indicates better care for the environment.

Comments
The level of order and cleanliness of a community, or other human activity (e.g., farm operation), can provide information on perspectives related to environmental health. Society has made no specific attempt to measure or comparatively evaluate this aspect.

Unfinished Business
- Need to determine how often the surveys would be conducted (i.e., what are the temporal trends this indicator would measure?).
- Need to determine how this indicator will be presented. For example, will a bar graph or a map be used?

Relevancies
Indicator Type: state
Environmental Compartment(s): humans
Related Issue(s): stewardship
SOLEC Grouping(s): **societal**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s): 11: Degradation of aesthetics

Last Revised
October 20, 1999

Economic Prosperity (Indicator ID: 7043)

Measure
Unemployment rates within the Great Lakes basin.

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 is a goal for all economies and humans are part of the ecosystem.

Endpoint
Achieving the lowest economically sustainable unemployment levels possible. Levels of unemployment under 5% in western societies are considered full employment.

Features
The indicator demonstrates the economic ability of humans to avoid abusive behaviour of the rest of the ecosystem. In a global context, wealthier nations (US and Canada, Europe) are more likely to also have better environmental management regimes because they can better afford them and can afford to avoid many of the highly exploitive choices with respect to the environment. Data on employment rates are collected regularly and frequently throughout the basin. The unemployment rate is a better indicator than gross domestic production per capita for this purpose since it focuses on human ability to meet their own needs through income provision and not necessarily through undesirable environmentally activities. For example, the oil spill from the Exxon Valdez increased gross domestic production, although it had a minimal effect on employment rates.

Illustration
The indicator will be best represented by a chart showing trends over years.

Limitations
The collection and presentation of the indicator information is not limited. It was noted in the World Commission on Environment and Development report “Our Common Future” that although economic well being is associated with higher levels of resource consumption and environmental degradation, higher levels of economic development afford the ability to better manage the ecosystem and can constrain unsustainable resource exploitation.

Interpretation
This indicator is useful in defining the extent to which society is meeting only human need and should be presented in the context of the other ecosystem indicators. Decreasing trends in unemployment may not correlate to improvements in the condition of the Great Lakes ecosystem. For example, higher employment levels may lead to greater spending, which may cause environmentally undesirable consequences, such as new sprawl development.

Comments
Since unemployment is determined from those actually seeking work, this is a good indicator of the degree to which society’s pursuit of economic prosperity is being met.

Currently unemployment rates in the U.S. are at almost historic lows. Although distribution of income may not be ideal, there is a sense that the human component of the ecosystem is better off than it was prior to this period. Arguments for excessive ecosystem exploitation can be countered as not being necessary.

Unfinished Business

Relevancies
Indicator Type: state
Environmental Compartment(s):
Related Issue(s):
SOLEC Grouping(s): **societal**
GLWQA Annex(es):
IJC Desired Outcome(s): 5: Economic viability
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
October 20, 1999

Water Withdrawal (Indicator ID: 7056)

Measure
Water use per capita in the Great Lakes basin.

Purpose
To assess the amount of water used in the Great Lakes basin per capita, and to infer the amount of wastewater generated and the demand for resources to pump and treat water.

Ecosystem Objective
Sustainable development is societal goal for the Great Lakes basin.

Endpoint
Resource conservation means reducing the amount of water that is used and the amount of wastewater that results from that water use. Current North American water use rates are in excess of 300 litres per day - reducing that by 50% is desirable and consistent with some European countries.

Features
The indicator provides a quantitative measure of the rate at which natural resources are being used. For example, high levels of water use results in considerable wastewater pollution, that results in degraded water quality, as well as increased demand for energy to pump and treat water. The indicator is a gross measure of water supplied through water supply facilities in a jurisdiction divided by the total number of people in the jurisdiction.

Illustration
The indicator will be displayed as the water use per capita in litres/capita within jurisdictions in the basin and the basin as a whole. The indicator is a measure of both residential and industrial/commercial water use.

Limitations
Data are readily abundant although it needs to be gathered in a consistent format. Ground water sources from private wells are excluded.

Interpretation
Water use symbolizes societal regard to resource use. North Americans, including those in the Great Lakes region, have very high rates of per capita water use compared with other developed nations, and reductions would result in reduced stress on the ecosystem. Water use is high and growing in places such as Toronto, in spite of efforts over the years to encourage water efficiency and conservation.

Comments
Canada and the United States are among the highest water using nations, per capita on the Earth.

Unfinished Business
< Need to add a discussion related to understanding the trends presented by the indicator. For example, will a baseline of “ideal” or “sustainable” water consumption rates need to be developed to determine if data collected on an annual basis (or another regular interval) reveals positive or negative trends in the amount of water consumed.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water, humans
Related Issue(s): stewardship
SOLEC Grouping(s): land use, **societal**
GLWQA Annex(es):
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 16, 2000

Energy Consumption (Indicator ID: 7057)

Measure
Energy use in kilowatt hours per capita.

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 GLWQA.

Endpoint
Resource conservation minimizing the unnecessary use of resources is an endpoint for ecosystem integrity and sustainable development.

Features
The indicator is useful on a state/province/country basin basis. The trend for energy use has been increasing over time, which this indicator will depict as it tracks annual energy use.

Illustration
The indicator will be shown as a measure of kilowatt hours electrical energy used per capita.

Limitations
While the data are readily abundant for electrical energy, it will be more difficult to assess other energy sources such as hydrocarbon used in transportation, wood burned in fireplaces, natural gas and furnace fuels. This will require considerable effort.

Interpretation
Energy is a key aspect of ecosystem sustainability. The second law of thermodynamics is a starting point to understanding the way in which energy plays a key role in long term sustainability. Reducing the use of energy of all kinds will reduce 'entropy' and ensure a more sustainable future. Although electrical energy is a good proxy for total energy use, a complete accounting of all energy used is desirable. Although all forms of energy should be considered for conservation, electrical energy is used as a proxy.

Comments
Canada and the United States are among the highest energy consuming nations on Earth.

The indicator provides a quantitative measure of the rate at which non-renewable natural resources are being used up and that renewables are being consumed.

Electrical energy generation is among the largest source of smog related pollutants. In addition, it also generates a major share of all greenhouse gases that are responsible for global climate change.

Unfinished Business
< Need to develop a more quantitative endpoint.
< Need to determine how this indicator will be presented - as a graph, on a map, etc?
< Need to develop a baseline or reference value to be used in assessing whether energy use is increasing or decreasing over time.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, humans
Related Issue(s): climate change, stewardship
SOLEC Grouping(s): land use, **societal**
GLWQA Annex(es): 15: Airborne toxic substances
IJC Desired Outcome(s):
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 16, 2000

Solid Waste Generation (Indicator ID: 7060)

Measure
Amount of solid waste generated per capita (tons and cubic metres).

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

Ecosystem Objective
Sustainable development is a generally accepted goal for Great Lakes basin society. This indicator supports Annex 12 of the GLWQA.

Endpoint
The reduction of waste to levels achieved in some European and Asian nations.

Features
Solid waste is generated and deposited on land or is incinerated and the residue remains on the land while other contaminants are redistributed by air and water sources. Solid waste represents a significant portion of all human land activities that generate waste and pollution and is stressful to the ecosystem. The indicator represents waste that goes to hazardous and non-hazardous landfills, as well as incinerators. Annual rates of waste generation will be presented by this indicator and bi-annual reporting will be useful.

Illustration
The indicator will be displayed as tons (tonnes) and cubic metres per capita in jurisdictions and for the basin over time. The indicator will be for all solid wastes over time.

Limitations
Although data are available for all jurisdictions, this indicator will require data coordination and integration. Variability in waste stream composition will result in the need for different types of measurement, such as weight versus volume, and may produce conflicting indications of progress. Regardless of the manner of disposal, the measure should consider the total volume of disposed solid waste. Therefore, important land contamination issues, such as acres of land fill space, will not be dealt with in this indicator.

Interpretation
Solid waste provides a measure of the inefficiency of human land based activities and the degree to which resources are wasted by the creation of waste. Reducing volumes of solid waste are indicative of a more efficient industrial ecology and a more conserving society. Reduced waste volumes are also indicative of a reduction in contamination of land through landfilling and incineration and thus reduced stress on the ecosystem.

Comments
Canada and the U.S. are among the highest waste producers on Earth. Reuse and recycling are opportunities to reduce solid waste levels.

Solid waste stored in sanitary landfills is a major source of methane, a very important greenhouse gas responsible for global climate change. Incineration of mixed solid waste has been shown to be a significant source of mercury and dioxins.

Unfinished Business
- Need to determine a specific endpoint.
- Need to determine a baseline value to use for assessing positive or negative trends in the amount of solid waste generated.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, land, humans
Related Issue(s): contaminants & pathogens, climate change, stewardship
SOLEC Grouping(s): **societal**
GLWQA Annex(es): 12: Persistent toxic substances
IJC Desired Outcome(s): 7: Virtual elimination of inputs of persistent toxic substances
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 16, 2000

Financial Resources Allocated to Great Lakes Programs
(Indicator ID: 8140)

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

Purpose
To assess the amount of dollars spent annually on Great Lakes programs, and to infer the responsiveness of Great Lakes programs through annual funding focused on research, monitoring, restoration, and protection of Great Lakes ecosystems by federal and state/provincial agencies and non-governmental organizations.

Ecosystem Objective
Programs should be responsive to the degradation of shoreline communities and species.

Endpoint
Fully funded research, monitoring, restoration, and protection programs for Great Lakes ecosystems.

Features
This indicator will track the amount of dollars spent annually on Great Lakes research, monitoring, restoration, and protection programs. It will assess the number of projects, funding levels, and number of researchers across various factors, including type of funding source (e.g., government, non-government, private sector); levels of governments (e.g., local, State, Federal); basin wide; lakewide; regions of special interest; and types of research and locations. Data collection for this indicator will require a survey of major funding agencies, organizations and universities to identify key individuals and types of research or projects. The trends illustrated by this indicator can be used to determine which areas/issues require additional support, and where there are opportunities to shift funding.

Illustration
Summary tables or graphs will be displayed for the entire basin and for each lake showing trends in the number of resources allocated for research, monitoring, restoration, and projection programs and projects.

Limitations
Because it is often difficult to determine the spatial focus of various research projects (e.g., nearshore versus coastal wetlands), this indicator may double-count, or overlook, resources allocated to projects. A lack of historical data will make the assessment of funding trends over time difficult. To date, there has been no effort to collect this data. To initiate such an effort, and examine trends every 3 to 5 years, would require a substantial commitment. Obstacles to information collection may include freedom of information issues and difficulties in assessing private sector research efforts.

Interpretation
This indicator could be used to compare investments in Biodiversity Investment Areas to overall program spending, or to other program areas such as restoration. A baseline will be established to determine what resources a program requires to be considered “fully funded.” This information will serve as a baseline to determine if the endpoint for this indicator has been achieved.

Comments
Received comments that this measure may be too dependent on political climate and not directly related to the benefits of the programs themselves. It is not clear how spending money is a meaningful or particularly sensitive societal response. This indicator should measure successful action. While it is agreed that this measure is not perfect, it can provide an initial estimate of the amount of attention given to various components of the Great Lakes ecosystem, such as nearshore terrestrial areas, over the long term. This indicator could be expanded to include factors such as the number of programs, policies, plans prepared, etc. as other indicators of agency interest.

This indicator may benefit from a ranking system that allows the return on investment to be assessed over time.
A change in funding levels may not be a reflection of the amount of attention the Great Lakes receive, but rather a reflection of budget issues.

Unfinished Business
< Need to determine a quantitative reference value, such as a particular dollar amount based on programs needs assessed on an annual basis.

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

Last Revised
Feb. 24, 2000

Climate Change: Number of Extreme Storms (Indicator ID: 4519)

Measure
For land areas adjacent to the Great Lakes, total number of "extreme storms", per year during ice-free and ice-break-up periods on the Great Lakes.

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

Ecosystem Objective
GLWQA General Objective: "These waters should be free from materials and heat directly or indirectly entering the water as result of human activity that . . . produce conditions that are toxic or harmful to human, animal or aquatic life." Change in atmospheric temperature will potentially affect the number of extreme storms in the Great Lakes region which will, in turn, affect coastal wetlands. Awareness of occurrence will encourage human response to reduce the stressor and minimize biological disruption.

Endpoint
An endpoint will need to be established, based on a literature search of historical data, if available, to determine the average number of extreme storms on the Great Lakes prior to a particular date.

Features
Extreme storm events are a natural stressor than can occur anywhere in the basin and can potentially alter coastal wetlands and indicators of wetland health. There is natural variability in occurrences of extreme storm events, but the interpretation method tries to account for this, so the final score should have lower variability over time. Criteria to define an "extreme storm" (e.g., any storm below a central atmospheric pressure threshold or above a wind speed threshold) must be set.

This indicator may show similar trends to other indicators of climate change (ie. 4857, First Emergence of Water Lily Blossoms in Coastal Wetlands and 4858, Ice Duration on the Great Lakes). It is indirectly linked to any other indicator that track trends in wetland area/habitat change.

Illustration
A graph with the total number of extreme storm events (not ice-bound) on the y axis and years on the x axis, beginning with the cut-off date for historical data. The graph will also indicate the historical median and extremes.

Limitations
This indicator assumes that: 1) of all storms, "extreme storms" alter coastal wetlands the most (due to the combined effects of wind and waves; 2) storms throughout the basin represent storm effects on wetlands throughout the basin; and 3) historical data is available. It may take some time to collect data and to define historical reference levels.

Interpretation
To interpret this indicator, data for "extreme storms" need to be gathered each year. From the recorded data of "extreme storms", the pre-1980 median, maximum and minimum will be determined. The historic range will be divided into 3 equally occurring ranges: below average, average, and above average (i.e., the number of extreme storms/year exceeded 0-33.3%, 33.3% to 66.7%, 66.7% to 100% of the years of record before 1980). The indicator will score high if the annual numbers of extreme storms for the previous 10 years are within the maximum and minimum historical extremes and they are distributed fairly evenly among the 3 historical ranges. Low scores will be obtained if any annual Extreme storm numbers of the previous 10 years lie beyond the maximum or minimum extremes or they are becoming highly skewed away from a fairly even distribution among the 3 ranges.

Water levels, fetch and direction of storms may affect how storms influence individual wetlands.

Comments
The concept of storm damage is very understandable to public.

An endpoint could be reached when the previous 10 years' values of numbers of extreme storms are evenly distributed within the pre-1980 historic range of number of extreme storms.

A technical report written by P.J. Lewis will provide a good starting point for historical data and assessment. The report was published by the Canadian Climate Centre, Technical Report #87-13, Severe Storms Over the Great Lakes: A Catalogue and Summary. 1957-1985. This report gives a fair amount of detail about each storm that had a least two reports of storm force winds (>48 knots) or greater.

Unfinished Business

- Need a definition of “extreme storms” - will it be based on wind speed, amount of precipitation, central atmospheric pressure of the storm, or the pressure gradient? Or some combination of two or more criteria.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air
Related Issue(s): climate change
SOLEC Grouping(s): coastal wetlands, nearshore terrestrial, **unbounded**
GLWQA Annex(es):
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
October 20, 1999

Climate Change: First Emergence of Water Lily Blossoms in Coastal Wetlands (Indicator ID: 4857)

Measure
The number of days after January 1 of first sighting of white on a water lily blossom, averaged over a representative set of coastal wetlands.

Purpose
To assess the change over time in first emergence dates of water lilies in coastal wetlands as a sentinel of climate change affecting the Great Lakes.

Ecosystem Objective
GLWQA General Objective: "These waters should be free from materials and heat directly or indirectly entering the water as result of human activity that . . . produce conditions that are toxic or harmful to human, animal or aquatic life." Change in temperature potentially affects most biota. Awareness of occurrence will encourage human response to reduce the stressor towards minimizing biological disruption.

Endpoint
An endpoint will need to be established, based on a literature search of historical data, if available, to determine the average historical emergence date of water lilies, and to determine the earliest and latest recorded dates of first emergence. If no historical data are available, the endpoint will need to be established from data gathered from monitoring this indicator.

Features
To monitor this indicator, a set of representative coastal wetland sites will be selected based on: 1) climate zones, 2) local observers and 3) associated historical data. The data will be collected annually. The data will have some variability due to natural climate variability and this will have to be considered when interpreting the data. Provided there are enough sites that meet the required criteria, collection and analysis of this indicator should be feasible.

This indicator may show similar trends to Ice Duration on the Great Lakes. It will be indirectly linked to indicators affected by climate change.

Illustration
A graph will be displayed showing, annually, the number of days after January 1 (average of the sites) of the first sighting of white on a water lily blossom. The average historical emergence data, and the earliest and latest recorded dates, will be marked for reference and comparison.

Limitations
A possible limitation may be locating sites that meet the needed criteria including on-site wetland observers and accessible water lilies. Monitoring would require frequent site visits for a period of time each year.

Interpretation
To interpret this indicator, data for the white water lily or for a highly correlated reference crop need to be gathered. From the recorded date of first emergence, the historical earliest and latest dates will be determined. The historic range will be divided into 3 equally occurring date ranges: early, average, and late. Scores will be designed to be high if the annual averages for the previous 10 years are within high and low historical extremes AND they are distributed fairly evenly among the 3 historical ranges. Low scores will be obtained if annual averages lie beyond the high or low extremes OR they are becoming highly skewed away from a fairly even distribution among the 3 ranges.

Comments
This indicator allows local people to become involved and aware of SOLEC. This indicator may have to be rethought if water lily data do not correlate well with historical data for a reference crop.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): biota
Related Issue(s): climate change
SOLEC Grouping(s): coastal wetlands, **unbounded**

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

Last Revised
Feb. 24, 2000

Climate Change: Ice Duration on the Great Lakes (Indicator ID: 4858)

Measure
Maximum percentage of Great Lakes area covered by ice each year.

Purpose
To assess the temperature and accompanying physical changes to each lake over time, and to infer potential impact of climate change on wetlands.

Ecosystem Objective
GLWQA General Objective: "These waters should be free from materials and heat directly or indirectly entering the water as result of human activity that . . . produce conditions that are toxic or harmful to human, animal or aquatic life." Change in water temperature (potentially due to global warming) will affect ice extent on the Lakes and, in turn, affect coastal wetlands. Awareness of occurrence will encourage human response to reduce the stressor towards minimizing biological disruption.

Endpoint
An endpoint will need to be established, based on a literature search of historical data to determine the average number of days per year that ice historically (prior to 1980) formed on each lake.

Features
Ice cover reflects temperature, wind, and heat stored in a lake, therefore, this is a good indicator of climate effects. This data is already collected annually for each lake by NOAA using satellite imagery. There is a natural variability in MAXIMUM ice extent accounted for in the interpretation.

This indicator may show similar trends to other indicators of climate change (ie. 4519, Number of Extreme Storms, 4857, First Emergence of Water Lily Blossoms in Coastal Wetlands, and 4861, Water Level Fluctuations). It is indirectly linked to any other indicator that track trends in wetland area/habitat change.

Illustration
A graph displaying the maximum percentage of ice cover on the y axis and years on the x axis. The historical median and extremes will be indicated.

Limitations
The data that have already been collected by NOAA are specific to each lake rather than coastal wetlands.

Interpretation
Even though it is unclear if storms alter ice extent, storms can break up ice and alter their formation, therefore, information regarding storms and their severity is needed to properly interpret this indicator.

To interpret this indicator, data for maximum percentage ice cover need to be gathered each year. From the period of record for maximum percentage of ice cover, the pre-1980 high and low extremes will be determined. The historic range will be divided into 3 equally occurring ranges of maximum per cent ice cover: below average, average, and above average (i.e., maximum per cent ice cover exceeded 0 to 33.3%, 33.3% to 66.7%, 66.7% to 100% of the pre-1980 years of record). The indicator will score high if the annual maximum percentage values for the previous 10 years are within the maximum and minimum historical extremes and they are distributed fairly evenly among the 3 historical ranges. Low scores will be obtained if any annual maximum percentage cover value lies beyond the high or low extremes or if the annual values are becoming highly skewed away from a fairly even distribution among the 3 ranges.

Comments
This is a very understandable feature. Lake ice indicates coastal wetland ice and itself affects wetlands (e.g., winter storm severity).

The endpoint is reached when the previous 10 years' values of maximum per cent ice cover are distributed evenly within the pre-1980 historic range of maximum per cent ice cover.

Unfinished Business

Relevancies
Indicator Type: pressure
Environmental Compartment(s): water
Related Issue(s): climate change
SOLEC Grouping(s): open waters, nearshore waters, coastal wetlands, **unbounded**
GLWQA Annex(es):
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Breeding Bird Diversity and Abundance (Indicator ID: 8150)

Measure
Diversity and abundance of breeding bird populations and communities in selected habitat types, and an avian index of biotic integrity.

Purpose
To assess the status of breeding bird populations and communities, and to infer the health of breeding bird habitat in the Great Lakes basin.

Ecosystem Objective
This indicator supports Annex 2 of the GLWQA.

Endpoint
For this indicator, the desired outcome would vary by species and habitat type. A target of no decline in area-sensitive bird species (forest/grasslands/savannah) could be established for a select group of species within each habitat type being sampled. A target of increasing populations of contaminant-sensitive bird species in coastal breeding territories could also be established and monitoring protocols designed to assess attainment. A target of 90% of the monitoring stations achieving species presence equal to 90% of the expected number based on habitat and range could be a third type of desired outcome.

Features
The Great Lakes basin supports a rich diversity of breeding bird species. This region is one of the most important regions on the North American continent for abundance and diversity of breeding birds. Long-term, comprehensive monitoring of the status and trends of bird populations and communities can allow resource managers to determine the health of bird communities and habitat conditions. Because breeding birds are strongly linked to habitat conditions, this indicator has potential to have cross applications to other wildlife taxa and other indicators.

An "index of biotic integrity" has been used successfully in other areas and while its application to bird communities is in the experimental stages, it should be considered. For this approach to be successful across the Great Lakes basin, reference areas with healthy bird communities would be identified and compared with other, potentially less healthy areas. Commonly-used indices of diversity (e.g., species richness, Shannon-Weiner, Simpson's) could be used to describe the health of the bird community in selected habitat types and could be tracked over time.

Illustration
Data from this indicator could be presented in a variety of ways. Population status and trends for bird species of interest could be illustrated by simple line graphs representing selected geographic areas or the whole basin. Comparison graphs showing area sensitive forest bird species and species pre-adapted to highly modified landscapes could be used to show effects of land use changes across the basin. Indices of biotic integrity for areas surveyed would be presented in bar graph form and compared to other areas for which the index has been calculated. Broader scaled biodiversity patterns across the Great Lakes basin could be presented in map form that identify key habitat areas (biodiversity investment areas, protected areas, biodiversity hot spots). These maps could also be used to illustrate changes in bird population patterns over time.

Limitations
Confidence in using these data to express the health of a large-scale, diverse ecosystem, would depend on having site specific data that adequately represented the range of habitat conditions in the region. For example, relying only on bird monitoring activity in National Parks, where disturbance and fragmentation of habitat is likely low, could result in overly optimistic pictures of population trends or ecosystem health. Conversely, reliance on data from easily accessible areas such as road-side counts, could lead to indices threat suggest conditions are worse than they really are. Data gathering for this indicator is personnel intensive during the short, early-summer breeding season. To adequately survey the Great Lakes basin will require large numbers of trained staff and substantial travel expenses.

Interpretation
Changes in abundance, density, and productivity are caused by many factors both on and off the breeding territories. Care must be used in determining the causes of these changes, especially for birds that spend much of each year on migration or in distant wintering habitats. Utilizing information from ongoing research and management on migration routes and wintering areas will be essential for interpreting these data.

Comments
Populations and communities of birds have been used to indicate a wide variety of ecological stressors and processes. Birds are abundant in many habitat types. They make up about 70% of the terrestrial vertebrate species in Great Lakes forests for example. Understanding population dynamics and habitat associations of breeding birds will aid in understanding major elements of ecosystem health.

By following a consistent protocol of 10 minute point counts by highly trained professional bird surveyors, stratifying points by habitat, prioritizing habitats to be surveyed, and conducting surveys only on rain-free, calm days, compatible data can be collected by many researchers and agency staff. Substantial agreement and consistency has already been achieved on survey methodology by researchers across the Great Lakes basin.

Habitat analysis and landscape assessment of the Great Lakes basin (see habitat cover indicators) would allow a monitoring protocol to be developed that would identify priority habitat types. It would also allow a stratified, random sampling design, based on relative area of habitat types to be developed. This would provide a more valid, robust and geographically integrated monitoring program than what now exists. Monitoring efforts ongoing in several National Forest (Superior, Chequamegon) and National Parks (Apostle Islands, Isle Royale) and the USFWS Breeding Bird Survey can be used to take model elements for developing this indicator. The Ontario Forest Bird Monitoring Program and Marsh Monitoring Program also provide site-specific data which could be integrated into this indicator. A Great Lakes basin-wide monitoring protocol for gathering habitat-specific information on the status and trends of bird populations and communities, coordinated with systematic, landscape-scale vegetation data will allow basin-wide biodiversity mapping based on bird populations. For most habitat types and bird taxa, monitoring is most efficient when survey data on all singing birds are collected. Multiple indices of ecosystem health can then be calculated based on data gathered.

This indicator allows interpretation at multiple scales. Population trends of an individual species within a limited geographic area provides useful information to land managers and may suggest specific management activities that should be undertaken. Comparisons of indices of biotic integrity among sites would provide a way to evaluate the variety of management strategies employed in similar environmental settings. Analysis of broad patterns, using biodiversity maps provide opportunities to identify landscape level activities that influence ecosystem health.

Expansion of ongoing monitoring and efforts to standardize data gathering and quality control would be one way to approach the development of this indicator with the funds that might realistically be expected.

Unfinished Business

Relevancies

Indicator Type: state
Environmental Compartment(s): biota
Related Issue(s): habitat
SOLEC Grouping(s): **unbounded**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised

Feb. 24, 2000

Threatened Species (Indicator ID: 8161)

Measure
Number, extent, and viability of species ranked as G1-G3 or S1-S3 in the Biological Conservation Database. A global or “G” rank is assigned on the basis of relative endangerment based primarily on the number of occurrences of the element globally. A rank of G1 means critically imperiled globally due to extreme rarity or due to factor(s) making it very vulnerable to extinction. A rank of G2 means imperiled globally due to rarity or due to some factor(s) making it very vulnerable to extinction throughout its range. A rank of G3 means either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range or due to other factors making it vulnerable to extinction throughout its range. A state or “S” rank focuses on the status of a species or ecosystem within the boundaries of a state. A rank of S1 means critically endangered with less than five known occurrences. A rank of S2 means six to twenty occurrences which are to some extent threatened. A rank of S3 means very rare or local throughout its range.

Purpose
To assess the number, extent and viability of threatened species, which are key components of biodiversity in the Great Lakes basin, and to infer the integrity of ecological processes and systems (e.g., sand accretion, hydrologic regime) within Great Lakes habitats.

Ecosystem Objective
Healthy populations of all vegetation and wildlife, including the rarest of species. This indicator supports Annexes 2 and 17 of the GLWQA.

Endpoint
Viable populations of G1-G3 or S1-S3 species that are stable and persistent over the long term, even though local populations may fluctuate significantly in time and space.

Features
The rarest species of an ecosystem are indicators of the health of and stresses on the ecosystem. This indicator would emphasize vascular plants for ease of sampling, and would include wildlife to the extent possible. Optimum sampling methods would need to be determined. Representative areas of large size (e.g. 10 km x 10 km square with appropriate habitat) would be selected with ecological subdivisions supporting the species, and sampled at 2-5 year intervals at coarse and fine scales to document locations, aerial extent, and numbers target species. Sampling area size and timeline for trend analysis might vary by species, depending on the habitat and life history. Comparison of successive sampling results would be used to identify short and long term trends. It would be important to select sampling areas that are ecologically relatively intact, as well as some with varying degrees of observable human impact.

Illustration
Graphs of population numbers for each target species over time per sampling site, ecoregion, and basin-wide.

Limitations
It would be costly to annually monitor all populations of all species. A subset could be sampled annually, to determine trends that might be applicable to the entire set. Certain species are more sensitive to change than others.

Interpretation
Natural environments are dynamic by nature, therefore, local decreases or even extirpations of a threatened species may be normal. On the other hand, local extirpations can also be linked to human alterations of habitats through activities such as development. Measures will need to be interpreted with contextual information on anthropogenic disturbances, and need to be taken over sufficient space and time to generate a "big picture" of metapopulations in contiguous or semi-contiguous habitats. Overall stability or increases in viable populations indicates integrity of key supporting processes to which the species are adapted. Overall decreases in population numbers and/or extent can signal deterioration of key processes that maintain suitable habitat.

Comments
Experts from the states/provinces should collectively decide which species would be the best indicators. Using the ranking system from the Biological Conservation Database provides a more uniform assessment of status across jurisdictions, and provides access to an existing digital database.

Unfinished Business
- Need to provide quantitative values for “viable populations.”

Relevancies
Indicator Type: state
Environmental Compartment(s): biota, fish
Related Issue(s): exotics, habitat
SOLEC Grouping(s): **unbounded**
GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring, 17: Research and development
IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 14: Loss of fish and wildlife habitat

Last Revised
Feb. 24, 2000

Acid Rain (Indicator ID: 9000)

Measure
1) Levels of pH in precipitation in the Great Lakes Basin, and 2) the area within the Great Lakes basin in exceedance of critical loadings of sulphate to aquatic systems, measured as wet sulphate residual deposition over critical load (kg/ha/yr).

Purpose
To assess the pH levels in precipitation and critical loadings of sulphate to the Great Lakes basin, and to infer the efficacy of policies to reduce sulphur and nitrogen acidic compounds released to the atmosphere.

Ecosystem Objective
The Canada/U.S. Accord on Air Quality pledges the two nations to reduce the emissions of acidifying compounds to the point where deposition containing these compounds does not adversely impact aquatic and terrestrial biotic systems. This indicator supports Annexes 1 and 15 of the GLWQA.

Endpoint
Levels of sulphate in wet deposition are not to exceed critical loads, defined by ecozone to be from 8 - 20 kg/ha/yr.

Features
Measurements of sulphate deposition and pH are made by the US NDDN and Canadian CAPMoN networks along with provincial and state partners. These data are stored in databases on both sides of the border.

Illustration
Data are routinely extracted from databases into annual maps of sulphate and pH deposition. These maps will be used to depict this indicator.

Limitations

Interpretation
This measure is not sufficient to fully understand the deposition problem and trends in pH concentration throughout the basin is another related indicator. Areas exceeding the sulphate critical load continue to be ecologically stressed due to high levels of acidity.

Comments
Current projections how that this may not occur until after 2010. The two specific measures tracked both provide indication of progress towards the goal of reducing acidifying substances.

Further progress in reduction of acidifying substances are required.

Unfinished Business
- Need to determine what the target pH level is.
- Need to add more information on how often measurements of sulphate and pH are made, and the spatial trends (i.e., location of monitoring sites within the Great Lakes basin) described by this indicator.

Relevancies
Indicator Type: pressure
Environmental Compartment(s): air, water, land
Related Issue(s): contaminants & pathogens
SOLEC Grouping(s): **unbounded**
GLWQA Annex(es): 1: Specific objectives, 11: Surveillance and monitoring, 15: Airborne toxic substances
IJC Desired Outcome(s): 9: Physical environmental integrity
GLFC Objective(s):
Beneficial Use Impairment(s):

Last Revised
Feb. 24, 2000

Exotic Species (Indicator Code: 9002)

Measure

Purpose
This indicator will assess the presence, abundance and distribution of invasive exotic species in the Great Lakes basin ecosystem and their impacts on ecosystem functioning. *This indicator is under development. It has been added to the SOLEC list in response to suggestions from multiple reviewers of the Version 3 list of SOLEC indicators.*

Ecosystem Objective

Endpoint

Features

Illustration

Limitations

Interpretation

Comments

Unfinished Business

Relevancies

Last Revised
Feb. 25, 2000