Forest Lands – Maintenance of Productive Capacity of Forest Ecosystems
Indicator # 8501

Note: This indicator includes three components and corresponds to Montreal Process Criterion 2, Indicators 10, 11, and 13.

Indicator #8501 Components:
Component (1) – Area of forest land and area of forest land available for timber production
Component (2) – Total merchantable volume of growing stock on forest lands available for timber production
Component (3) – Annual removal of wood products compared to net growth, or the volume determined to be sustainable (proposed for future analysis; data not presented in this report)

Overall Assessment

Status:	**Not Assessed**
Trend:	**Undetermined**
Primary Factors Determining Status and Trend	**Additional discussion amongst forestry experts is needed for an assessment determination.**

Lake-by-Lake Assessment

Lake Superior

Status:	Not Assessed
Trend:	Undetermined
Primary Factors Determining Status and Trend	U.S. data by individual lake basin is not available.

Lake Michigan

Status:	Not Assessed
Trend:	Undetermined
Primary Factors Determining Status and Trend	U.S. data by individual lake basin is not available.

Lake Huron

Status:	Not Assessed
Trend:	Undetermined
Primary Factors Determining Status and Trend	U.S. data by individual lake basin is not available.

Lake Erie

Status:	Not Assessed
Trend:	Undetermined
Primary Factors Determining	U.S. data by individual lake basin is not available.

Status and Trend

Lake Ontario

Status:	Not Assessed
Trend:	Undetermined
Primary Factors Determining Status and Trend	U.S. data by individual lake basin is not available.

Purpose

- To determine the Great Lakes forests' capacity to produce wood products
- To allow for future assessments of changes in productivity over time, which can be representative of social and economic trends affecting management decisions and can also be related to ecosystem health

Ecosystem Objective

To maximize the productive capacity of Great Lakes forests while maintaining the ecosystem's health and sustainability.

State of the Ecosystem

Component (1):

The total area of forest land analyzed in the Great Lakes basin for this report was 35,113,242 hectares. Of this area, about 89% (or a total of 31,194,790 hectares) can be considered as available for timber production, as calculated from U.S. timber land estimates and Canadian productive forests not restricted from harvesting. In the U.S. portion of the basin, the proportion of land available for timber production increased to about 91%, while the value decreased to 86% for the entire Canadian portion of the basin and then rose to 91% for Ontario's managed forests. Complete U.S. data broken down by state and Canadian data broken down by lake basin can be viewed in Tables 1 and 2, respectively.

The amount of forest land available for timber production is directly related to the productive capacity of forests for harvestable goods. This proportion is affected by different types of management activities, which provides an indication of the balance between the need for wood products with the need to satisfy assorted environmental concerns aimed at conservation of biological diversity.

Component (2):

In the analyzed area of Great Lakes basin forests available for timber production, 78% of the total wood volume was merchantable. This percentage of growing stock increased to 92% for the U.S. portion of the basin and decreased to 61% for Ontario's managed forests in the Canadian part of the basin. Complete U.S. data broken down by state and Canadian data broken down by lake basin can be viewed in Tables 3 and 4, respectively.

If the values of net merchantable volume are compared to the total area of forest land available for timber production, a rough estimate of the forests' productive capacity can be obtained. This puts U.S. forests' per-unit-area productivity at a value of 92.7 cubic meters per hectare (m^3/ha), and Canadian forests' at 90.2 (m^3/ha).

Changes in productivity values can be indicative of the ecosystem's health and vigor, as a lowered ratio of merchantable volume to available timber land can suggest reduced growth and ability of trees to absorb nutrients, water and solar energy and increased disease and tree mortality. Further assessment of productive capacity would require additional historical data and analysis by forestry experts.

Component 3:
The growth to removal ratio is often used as a course surrogate for the concept of sustainable production in the U.S. Although exact data for this measure have not been compiled for this report, nationwide U.S. studies have shown that timber growth has exceeded removals for several decades, and Ontario's wood removals on managed timber land is supposedly done within sustainable limits by definition of the forestry practices enacted in those areas.

Pressures
Fluctuating marketplace demands for wood products and increased pressures to reserve forest lands for recreation, conservation of biodiversity and wildlife habitat can affect the volume of timber available for harvest.

Disease and disturbance from fires or other events can also affect productivity capacity.

Management Implications
Timber productivity can be increased through the use of timber plantations and sustainable management of forests available for timber production.

Continued discussion of the meaning of sustainability and how it is affected by wood product removal is crucial to the effectiveness of future management decisions.

Comments from the author(s)
It can be difficult to analyze forest areas and growing stocks for a set moment in time, because inventory time frames can vary. U.S. 2002 RPA data are compiled from a range of different years (1989-1998 for Great Lakes states) depending on when the most recent state inventories were conducted. This issue should diminish as the FIA switches to an annualized survey cycle, and future analyses should therefore incorporate this data.

Although Canadian data are available by watershed, U.S. forest data are compiled by county for this report, so the area of U.S. land analyzed is not necessarily completely within the Great Lakes basin. Corresponding data may be skewed. This factor makes it difficult to represent the data by individual lake basin. Additional GIS analysis of the U.S. raw inventory data would be required to provide forest data by watershed.

Area of timber land in the U.S. is used as a proxy for the net area land available for timber production in U.S. data calculations, but timber land area may include currently inaccessible and inoperable areas or areas where landowners do not have timber production as an ownership objective, and is therefore an overestimation of the net area available for timber production and associated merchantable wood volumes.

Canadian data for growing stock is only available for Ontario's managed forests where Forest Resources Planning Inventories occur. This area is commonly referred to as the Area of the Undertaking (AOU), and only represents 72% of Ontario's total Great Lakes basin land area and 78% of its total forest area. The rest of the Canadian part of the basin is restricted to satellite data capabilities.

Data for annual removal of wood products as compared to net growth is available for Canada and a few of the U.S. Great Lakes states, but was not prepared for the Great Lakes basin at the time of this report. This information should be compiled for future analyses when available, and is an important ratio to monitor over time to ensure that wood harvesting is not reducing the total volume of trees on timber land at larger spatial scales. Unfortunately this value does not add much insight to the detailed ecological attributes of sustainability, and must be analyzed with additional biological components to achieve this indicator's ecosystem objective.

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Data Sources

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http://ncrs2.fs.fed.us/4801/fiadb/rpa_tabler/webclass_rpa_tabler.asp . Data supplied by Eric Wharton, USDA Forest Service, ewharton@fs.fed.us .

List of Tables

Table 1. Area of forest land available for timber production* in relationship to total area of forest land in U.S. Great Lakes basin counties
Caption: * Area designated as timber land is used as a proxy for this value and may include inaccessible areas. The presented data should therefore be considered an over-estimation of the net area available for timber production.
Source: USDA Forest Service, Forest Inventory and Analysis National Program, 2002 Resource Planning Act (RPA) Assessment Database

Table 2. Area of forest land available for timber production in relationship to total area of forest land in, A) Canadian Great Lakes basin, and B) the AOU* portion of Ontario

Caption: * The Area of the Undertaking (AOU) land area represents 72% of Ontario's total Great Lakes basin land area and 78% of its total forest area.
Source: Ontario Ministry of Natural Resources, Forest Standards and Evaluation Section. Landsat Data based on Landcover 2002 (Landsat 7) classified imagery, Inventory data based on Forest Resources Planning Inventories, and NRVIS coverages

Table 3. Total volume of growing stock* in U.S. Great Lakes basin counties
Caption: * Calculations do not take inaccessibility or inoperability of timber land into account, so resulting values are skewed high
Source: USDA Forest Service, Forest Inventory and Analysis National Program, 2002 Resource Planning Act (RPA) Assessment Database

Table 4. Total volume of growing stock in Canadian Great Lakes basin*
Caption: * Data only available for Ontario's managed forests (AOU portion of Ontario)
Source: Ontario Ministry of Natural Resources, Forest Standards and Evaluation Section. Landsat Data based on Landcover 2002 (Landsat 7) classified imagery, Inventory data based on Forest Resources Planning Inventories, and NRVIS coverages

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State	Total Area of Forest land (ha)	Area of Forest Land Available for Timber Production* (ha)	% Available for Timber Production*
Illinois	29,322	5,634	19.21%
Indiana	198,351	182,287	91.90%
Michigan	7,802,663	7,533,587	96.55%
Minnesota	3,345,320	2,818,676	84.26%
New York	4,775,982	3,928,686	82.26%
Ohio	742,161	668,190	90.03%
Pennsylvania	223,904	210,992	94.23%
Wisconsin	3,086,921	3,033,084	98.26%
Total	**20,204,626**	**18,381,137**	**90.97%**

Table 1. Area of forest land available for timber production* in relationship to total area of forest land in U.S. Great Lakes basin counties
Caption: * Area designated as timber land is used as a proxy for this value and may include inaccessible areas. The presented data should therefore be considered an over-estimation of the net area available for timber production.
Source: USDA Forest Service, Forest Inventory and Analysis National Program, 2002 Resource Planning Act (RPA) Assessment Database

A) Canadian Great Lakes Basin			
Lake Basin	Total Area of Forest Land (ha)	Net area of Forest Land Available for Timber Production (ha)	% Available for Timber Production
Superior	7,061,238	6,006,356	85.06%
Huron	6,162,419	5,343,401	86.71%
Erie	322,317	291,107	90.32%
Ontario	1,362,643	1,172,788	86.07%
Totals	**14,908,617**	**12,813,653**	**85.95%**

B) AOU* Portion of Ontario			
Lake Basin	Total Area of AOU's Forest Land (ha)	Net area of AOU Forest Land Available for Timber Production (ha)	% Available for Timber Production
Huron	4,710,406	4,227,743	89.75%
Ontario	665,100	611,268	91.91%
Superior	6,227,943	5,749,905	92.32%
Totals	**11,603,450**	**10,588,917**	**91.26%**

Table 2. Area of forest land available for timber production in relationship to total area of forest land in, A) Canadian Great Lakes basin, and B) the AOU* portion of Ontario
Caption: * The Area of the Undertaking (AOU) land area represents 72% of Ontario's total Great Lakes basin land area and 78% of its total forest area.
Source: Ontario Ministry of Natural Resources, Forest Standards and Evaluation Section. Landsat Data based on Landcover 2002 (Landsat 7) classified imagery, Inventory data based on Forest Resources Planning Inventories, and NRVIS coverages

State	Total Live Volume* (m^3) on Forest Lands Available for Timber Production	Net Merchantable Volume (m^3) of Timber Products (Growing Stock*)	Volume (m^3) of Non-merchantable Timber Products	% Growing Stock* (of Total Vol. Available for Timber Production)
Illinois	518,577	500,423	18,154	96.50%
Indiana	22,162,859	18,342,594	3,820,265	82.76%
Michigan	829,796,679	754,964,965	74,826,151	90.98%
Minnesota	219,781,880	199,559,859	20,222,021	90.80%
New York	383,181,677	365,098,413	18,083,264	95.28%
Ohio	73,836,032	71,466,897	2,369,136	96.79%
Pennsylvania	25,840,363	24,880,573	959,790	96.29%
Wisconsin	294,891,458	269,125,981	25,765,478	91.26%
Total	**1,850,009,525**	**1,703,939,705**	**146,064,258**	**92.10%**

Table 3. Total volume of growing stock* in U.S. Great Lakes basin counties
Caption: * Calculations do not take inaccessibility or inoperability of timber land into account, so resulting values are skewed high
Source: USDA Forest Service, Forest Inventory and Analysis National Program, 2002 Resource Planning Act (RPA) Assessment Database

Lake Basin	Total Volume (m^3) on Forest Lands Available for Timber Production	Net Merchantable Volume (m^3) of Timber Products (Growing Stock)	Volume (m^3) of Non-merchantable Timber Products	% Growing Stock (of Total Vol. Available for Timber Production)
Huron	667,854,390	421,077,634	246,776,756	63.05%
Ontario	114,963,698	72,717,983	42,245,715	63.25%
Superior	787,640,995	461,410,679	326,230,315	58.58%
Totals	**1,570,459,083**	**955,206,296**	**615,252,787**	**60.82%**

Table 4. Total volume of growing stock in Canadian Great Lakes basin*
Caption: * Data only available for Ontario's managed forests (AOU portion of Ontario)
Source: Ontario Ministry of Natural Resources, Forest Standards and Evaluation Section. Landsat Data based on Landcover 2002 (Landsat 7) classified imagery, Inventory data based on Forest Resources Planning Inventories, and NRVIS coverages

Forest Lands – Conservation and Maintenance of Soil and Water Resources
Indicator #8503

Note: This indicator includes two components and corresponds to Montreal Process Criterion 4, Indicator 19

Indicator #8503 Components:

Component (1) – Percent of forested land within riparian zones by watershed and percent of forested land within watershed by Lake basin

Component (2) – Change in area of forest lands certified under sustainable forestry programs in Great Lakes states and Ontario

Overall Assessment

Status:	**Mixed**
Trend:	**Undetermined**
Primary Factors Determining Status and Trend	**Trend information is not available for forested areas at this time. Data for the area of certified forest lands can not be analyzed according to Great Lakes Basin boundaries at this time, but the overall area of certified lands is increasing across the region.**

Lake-by-Lake Assessment

Lake Superior

Status:	Good
Trend:	Undetermined
Primary Factors Determining Status and Trend	A large proportion of the basin's riparian zones and watersheds are forested. Certification data does not exist specific to this individual lake basin.

Lake Michigan

Status:	Mixed
Trend:	Improving, Unchanging, Deteriorating or Undetermined
Primary Factors Determining Status and Trend	Just over half of the basin's riparian zones and watersheds are forested. Certification data does not exist specific to this individual lake basin.

Lake Huron

Status:	Mixed
Trend:	Undetermined
Primary Factors Determining Status and Trend	Over half of the basin's riparian zones and watersheds are forested. Certification data does not exist specific to this individual lake basin.

Lake Erie

Status:	Poor
Trend:	Undetermined
Primary Factors Determining	Only a small portion of the basin's riparian zones and watersheds are forested. Certification data does not exist specific to this individual lake

Status and Trend	basin.

Lake Ontario

Status:	Mixed
Trend:	Undetermined
Primary Factors Determining Status and Trend	Just over half of the basin's riparian zones and watersheds are forested. Certification data does not exist specific to this individual lake basin.

Purpose
- To describe the extent to which Great Lakes basin forests aid in the conservation of the basin's soil resources and protection of water quality.
- To describe the level of Great Lakes states' and Ontario's participation in sustainable forestry certification programs.

Ecosystem Objective
Improved soil and water quality within the Great Lakes basin.

State of the Ecosystem
Component (1):
Forests cover about 61% of the total land and 70% of the riparian zones (defined as the 30 meter buffer around all surface waters) within the Great Lakes basin. This trend of a slightly greater percentage of forested land by riparian zone as opposed to by overall watershed is repeated for every major lake basin for the Great Lakes basin as a whole, (see Figure 2).

The U.S. portion of the basin (including the upper St. Lawrence River watersheds) has forest coverage on 61% of its riparian zones (as of 1992), and the Canadian portion of the basin (excluding the upper St. Lawrence River watersheds) has forest coverage on 76% of its riparian zones (as of 2002), (see Table 1). Lake Superior has the best coverage overall, with forested lands covering 96% of its riparian zones. Lakes Michigan (62%), Huron (74%) and Ontario (61%) all have at least half of their total riparian zones covered with forests, while Lake Erie has only 30% coverage. The percentages of forested riparian zones by watershed are visually represented in Figure 1 and are available summarized by Lake Basin in Figure 2.

While good water quality is generally associated with heavily forested or undisturbed watersheds, (USDA 2004) the existence of a forested buffer near surface water features can also protect soil and water resources despite the land use class present in the rest of the watershed, (Carpenter *et. al* 2003). As the percentage of forest coverage within a riparian zones increases, the amount of runoff and erosion (and therefore nutrient loadings, non-point source pollution and sedimentation) decreases and the capacity of the ecosystem to store water increases. Studies show that heavy forest cover is capable of reducing total runoff by as much as 26% as compared to treeless areas with equivalent land-use conditions, (Sedell, *et. al* 2000) and that riparian forests can reduce nutrient and sediment loadings by 30-90%, (Alliance for the Chesapeake Bay, 2004).

Biodiversity of aquatic species is further maintained in riparian areas with increased forest coverage by an increase in the amount of large woody debris (which affects stream configuration, regulation of organic matter and sediment storage, and aquatic habitat availability) and decreased water temperatures, (Eubanks *et. al* 2002). A study completed in Pennsylvania by Lynch *et. al* in 1985 claimed that complete commercial clear cutting of a riparian zone allowed a 10 ˚*C rise in* stream water temperatures, but the retention of a forested buffer strip only allowed an increase of about 1 ˚*C, (Binkley and MacDonald 1994).* This regulation of water temperatures can be critical to the maintenance of assorted cold-water fisheries like trout.

The lack of consensus on the desired percentage of forested land in the basin or riparian zone (and the desired size of the riparian zone itself) makes it difficult to determine the specific implications of the presented data. Comparisons to historical forest cover in riparian zones and manipulative experiments would be useful for trend establishment.

<u>Component (2)</u>:
Sustainable forestry management programs are designed to ensure timber can be grown and harvested in ways that protect the local ecosystem. Participation is often voluntary, but once certification is gained, compliance with management protocols is required. Data from three different certification programs was analyzed for this report. It should be noted that their numbers are not additive, as one area of land can be certified under more than one program at a time.

The area of forest lands certified under the Sustainable Forestry Initiative (SFI®) program increased by 855% from 2003 to 2005 across the Great Lakes region, (see Figure 3). Forest landowners who only elect to enroll in the program, but not go through the formal certification process, often choose to follow the forest management protocols, but are not required to do so until they seek certification. It is therefore possible that a much greater amount of forest lands are being managed according to these sustainable practices than is represented by the given data.

Certification in two other sustainable forestry programs also grew in the U.S. Great Lakes states over the past few years, (see Figure 4). The acres of forest lands certified by the American Tree Farm System (ATFS) rose by 47% between 2004 and 2005. The ATFS is a voluntary certification program for non-industrial, private landowners, and states it's mission as, "To promote the growing of renewable forest resources on private lands while protecting environmental benefits and increasing public understanding of all benefits of productive forestry," (American Forest Foundation, 2004). The Forest Stewardship Council (FSC) is an international body that accredits certification organizations and guarantees their authenticity. Acres of forest lands certified under this organization grew by 50% between 2005 and 2006.

This rise in the area of certified forest lands under all three programs can be interpreted as a greater commitment to sustainable forest management amongst forest industry professionals. The assumption is that continued growth in sustainable management practices will lead to improved soil and water resources in the areas where they are implemented.

Pressures
Component (1): The same pressures exerted on all forest resources also apply here. Development of forest lands to other land use classes (such as developed, agricultural, or pasture) decreases the amount of forest area across watersheds and in riparian zones. Urbanization and

seasonal home construction can specifically impact riparian areas since they are among the most desirable development locations.

Component (2): Participation in sustainable forestry programs can be affected by marketplace popularity. Political climate, status of the economy, and public opinion can all influence forest managers decisions to gain certification.

Management Implications

Component (1): Development of policy directed towards protecting forested lands within riparian zones would help maintain forested buffers near surface waters, thereby leading to a possible improvement of local ecosystem health regardless of the land use classification in the rest of the watershed.

Component (2): Increased reporting of certification data by watershed would make corresponding analyses easier. Greater participation in sustainable forestry certification programs would ensure that all timberland is managed in a sustainable manner.

Comments from the author

Component (1): For the purposes of this report, riparian zone was defined as 30 meters on each side of a surface water feature. Research shows that a forested buffer of this size achieves the widest range of water quality objectives, (Alliance for the Chesapeake Bay, 2004), and is the standard value used in USGS Forestry Service, Northeastern Area. Other sources quote different amounts of forested buffer needed near surface water features to achieve the highest level of soil and water resources protection, ranging anywhere from 8-150 meters from the water's edge, (Illinois, Indiana, and Ohio Departments of Natural Resources, 2006). The ideal riparian zone size can be affected by a variety of factors such as stream, vegetation and soil type, geomorphology, slope of land, and season, (Eubanks *et. al*, 2002).

The resolution of the US landcover dataset used in this analysis was coarse enough to cause slight inaccuracies, but the data was determined as suitable for summarization at the watershed scale.

Additional research of existing literature would be helpful in further quantifying the effects of riparian forests on erosion, run-off, water temperatures, and nutrient and pollutant storage. Although specific studies have been done on these topics, the differences in metrics and sample locations complicate comparisons for the Great Lakes Basin.

Component (2): In subsequent analyses, data should be collected for the percent of forested riparian zones that lie within areas also certified in sustainable forestry programs. Presently, certification data cannot be analyzed by watershed or riparian area, and is therefore less useful for any analyses other than assessment of changing trends in the programs' utilization.

Expanding this component to include rates of compliance with Forestry Best Management Practices (BMPs) would provide valuable information for additional analyses. While certification in sustainable forestry programs often includes the implementation of BMPs, not all forest lands managed according to BMPs are also certified. Forestry BMPs have been developed in all Great

Lakes states and provinces, so obtaining the relevant audit data would provide a greater and more detailed information base relating to the conservation of forest, soil and water resources.

Many BMPs are directed at reducing non-point source pollution and some states even have monitoring data relating to issues such as water quality. For example, Wisconsin's Forestry Best Management Practices for Water Quality Report stated that, when BMPs were correctly applied to areas where they were needed, 96% of the monitored area showed no adverse impact on water quality, (Breunig *et. al* 2003). It is generally accepted that this trend exists in other states as well. For although individual states' BMPs may differ, studies have shown that their correct implementation results in effective protection of water quality overall.

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USDA Forest Service, Northeastern Area State and Private Forestry, Information Management and Analysis. 2006. Forest land by Watershed. Data supplied by Rebecca Whitney, USDA Forest Service, rwhitney@fs.fed.us .

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Table 1. Percent of Land Forested within U.S. and Canadian Great Lakes Watersheds and Riparian Zones by Lake Basin.

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US data: USDA Forest Service, Northeastern Area State and Private Forestry, Information Management and Analysis. 2005. Riparian Area Land Cover Types based on the 1992 National Land Cover Dataset. Lake Basin boundaries refined by U.S. EPA, Great Lakes National Program Office.

Canadian data: Ontario Ministry of Natural Resources, Forest Standards and Evaluation Section. Landsat Data based on Landcover 2002 (Landsat 7) classified imagery, Inventory data based on Forest Resources Planning Inventories and NRVIS watershed coverage (1994).

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Ontario Ministry of Natural Resources – NRVIS Watershed Coverage (1994); Landcover (2002); Riparian Areas created by Forest Evaluation Section
Map data from USDA Forest Service, Information Management and Analysis Group, Durham, NH and U.S. EPA, Great Lakes National Program Office.
Map created by U.S. EPA, Great Lake National Program Office, Technical Assistance and Analysis Branch

Figure 2. Percent of Land Forested within Great Lakes Watersheds and Riparian Zones by Lake Basin.
Caption for figure 2: * = Upper St. Lawrence data only available for U.S.
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Figure 3. Forest Lands Certified Under SFI in the Great Lakes region (U.S. States and province of Ontario), 2003-2005.
Data Source:
Personal communication with Jason Metnick, SFI Label and Licensing, Sustainable Forestry Board, 2006.

Figure 4. Forest Lands Certified Under ATFS and FSC in the Great Lakes States (U.S. only). Data provided by Sherri Wormstead of the USDA Forestry Service (swormstead@fs.fed.us) using following sources:
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ATFS data source: Program Statistics (January 2005) (provided by Emily Chan, American Forest Foundation, by e-mail on 11-4-2005)

Last updated
SOLEC 2006

Basin	U.S. (1992)		Ontario (2002)	
	% Forested (Entire Watershed)	% Forested (Riparian Areas)	% Forested (Entire Watershed)	% Forested (Riparian Areas)
Lake Superior	87.73%	88.44%	98.60%	98.05%
Lake Michigan	51.54%	61.90%		
Lake Huron	55.07%	54.28%	74.65%	77.04%
Lake Erie	22.90%	36.24%	14.30%	19.95%
Lake Ontario	52.15%	63.25%	49.99%	59.28%
St. Lawrence River	84.10%	87.03%		
Totals	**53.13%***	**60.43%***	**73.05%****	**75.67%****

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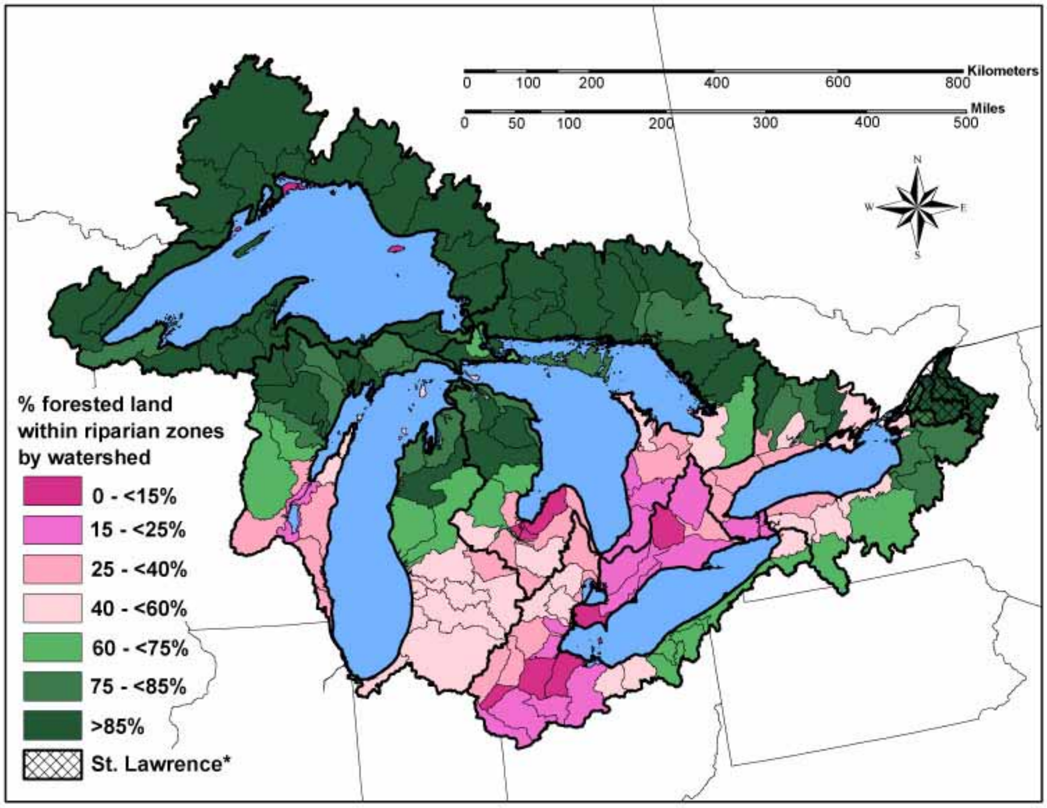

Figure 1. Percent Forested Land within Riparian Zones by Watershed in the Great Lakes Basin. *The area within the St. Lawrence River drainage does not actually drain into the Great Lakes basin, but is still included in the Great Lakes basin by definition in the Clean Water Act and the Great Lakes Water Quality Agreement.
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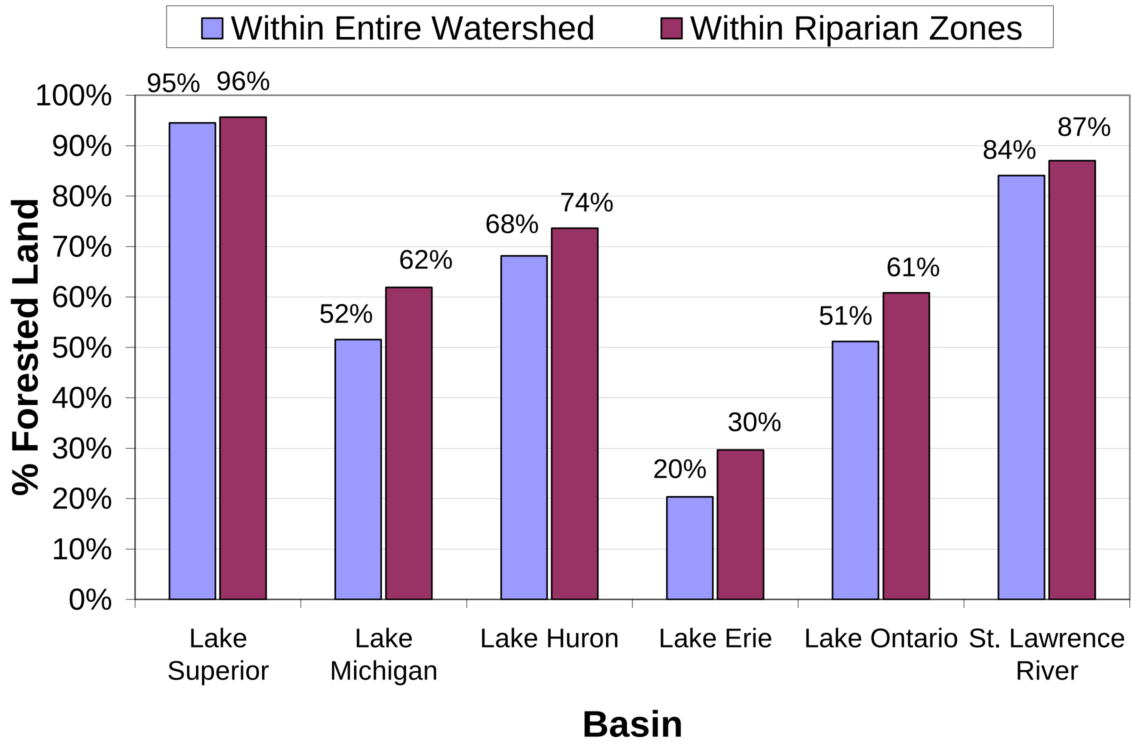

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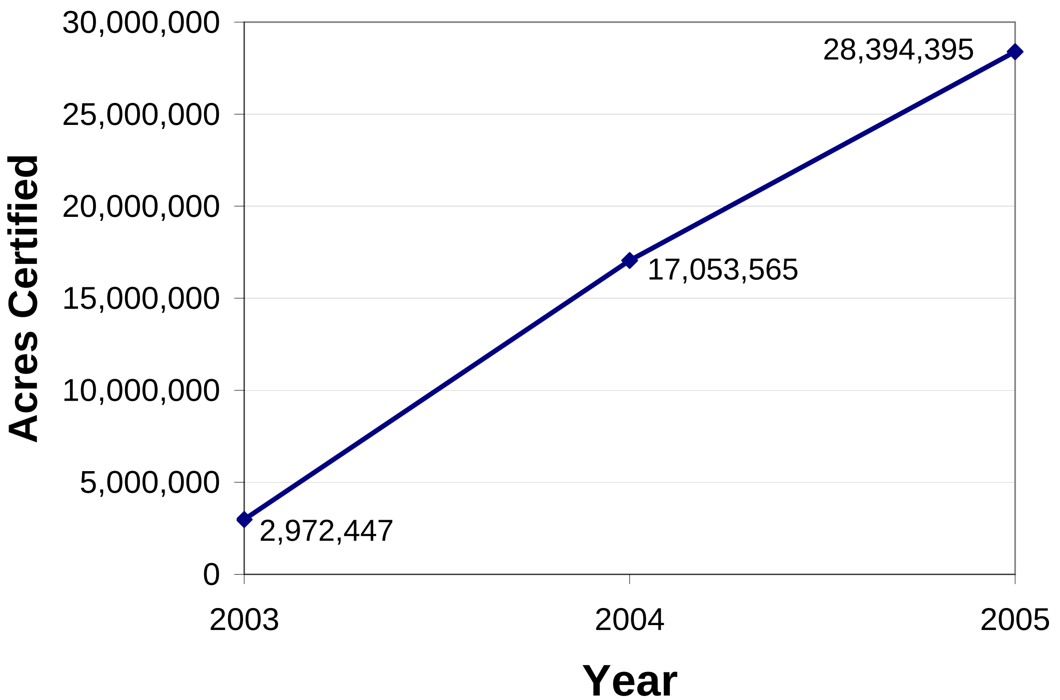

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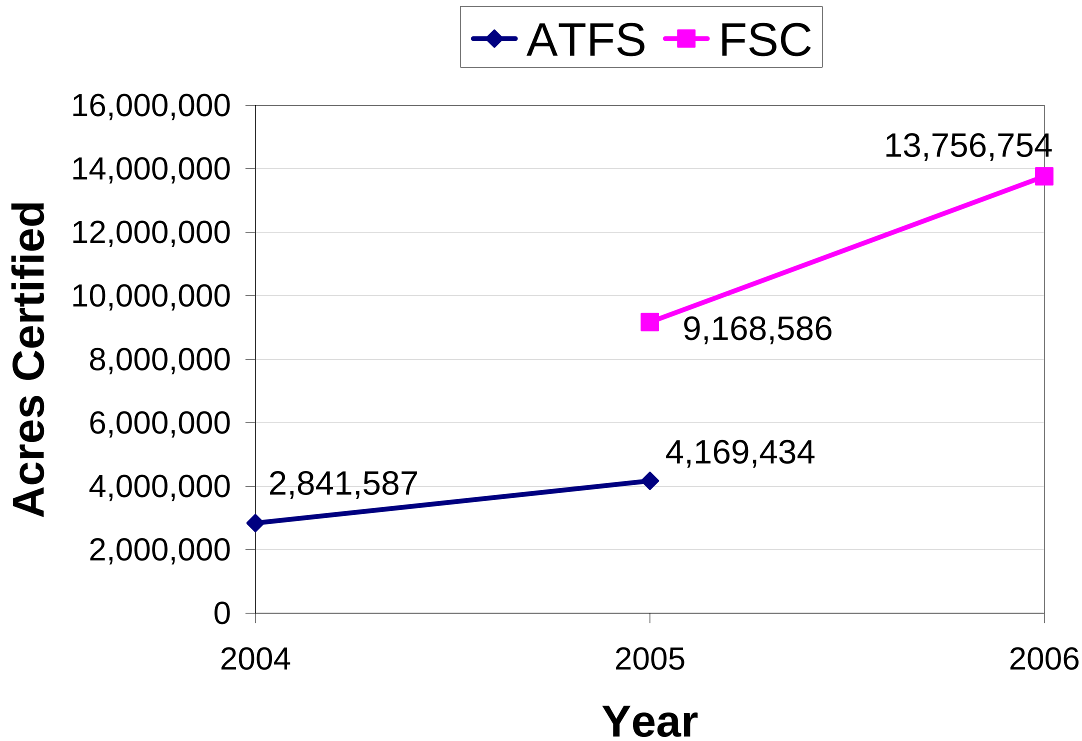

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Acid Rain
Indicator #9000

Assessment: Mixed, Improving

Purpose
- To assess the pH levels in precipitation;
- To assess the critical loads of sulfate to the Great Lakes basin; and
- To infer the efficacy of policies to reduce sulfur and nitrogen acidic compounds released into the atmosphere.

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

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

Lakes and rivers have been acidified by acid rain, directly or indirectly causing the disappearance of invertebrates, many fish species, waterbirds and plants. Not all lakes exposed to acid rain become acidified, however. Lakes located in terrain that is rich in calcium carbonate (e.g. on limestone bedrock) are able to neutralize acidic deposition. Much of the acidic precipitation in North America falls in areas around and including the Great Lakes basin. Northern Lakes Huron, Superior and Michigan, their tributaries and associated small inland lakes are located on the geological feature known as the Canadian Shield. The Shield is primarily composed of granitic bedrock and glacially derived soils that cannot easily neutralize acid, thereby resulting in the acidification of many small lakes (particularly in northern Ontario and the northeastern U.S.). The five Great Lakes are so large that acidic deposition has little effect on them directly. Impacts are mainly felt on vegetation and inland lakes in acid-sensitive areas.

A recent report published by the Hubbard Brook Research Foundation has demonstrated that acid deposition is still a significant problem and has had a greater environmental impact than previously thought (Driscol *et al*. 2001). For example, acid deposition has altered soils in the northeastern U.S. through the accelerated leaching of base cations, the accumulation of nitrogen and sulfur, and an increase in concentrations of aluminum in soil waters. Acid deposition has also contributed to the decline of red spruce trees and sugar maple trees in the eastern U.S. Similar observations have been made in eastern Canada (Ontario and eastward) and are reported in the 2004 Canadian Acid Deposition Science Assessment (Environment Canada 2005). The assessment confirms that although levels of acid deposition have declined in eastern Canada over the last two decades, approximately 21% of the mapped area currently receives levels of acid rain in excess of what the region can handle, and 75% of the area is at potential risk of damage should all nitrogen deposition become acidifying, i.e. aquatic and terrestrial ecosystems become nitrogen saturated.

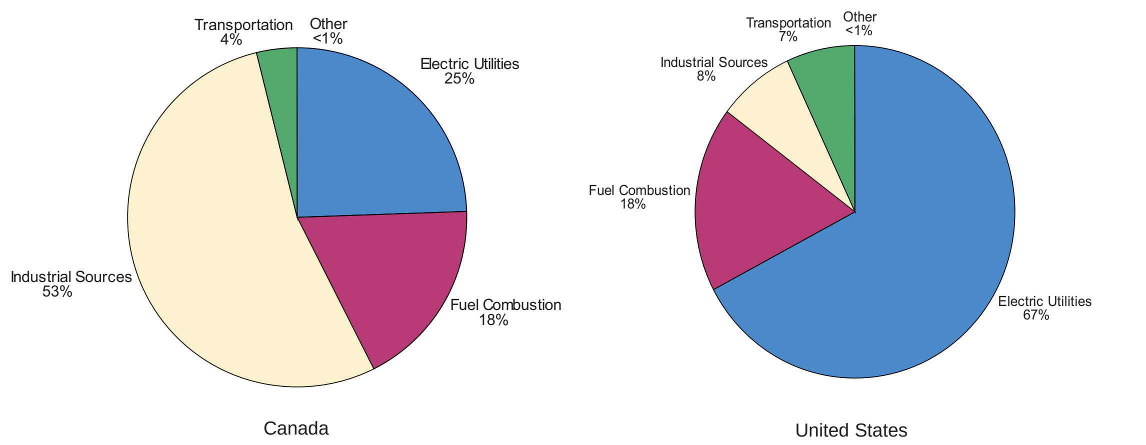

Figure 1. Sources of Sulfur Dioxide Emissions in Canada and the U.S. (1999)
Source: Figure 4 of Canada - United States Air Quality Agreement: 2002 Progress Report. http://www.epa.gov/airmarkets/usca/airus02.pdf and Environment Canada 1999 National Pollutant Release Inventory Data and U.S. Environmental Protection Agency 1999 National Emissions Inventory Documentation and Data

By 2000, Canadian NO_x emissions were reduced by more than 100,000 tonnes below the forecast level of 970,000 tonnes (established by Acid Rain Annex) at power plants, major combustion sources, and smelting operations. In the U.S., reductions in NO_x emissions have significantly surpassed the 2 million ton reduction for stationary and mobile sources mandated by the Clean Air Act Amendments of 1990. Under the Acid Rain Program alone, NO_x emissions for all the affected sources in 2002 were 4.5 million tons, about 33% lower than emissions from the sources in 1990. Overall NO_x emissions decreased by about 12% in the U.S. from 1993 to 2002 and remained relatively constant in Canada since 1990, but they are projected to decrease considerably in both countries by 2010. For additional information on SO_2 and NO_x emission reductions, including sources outside the Acid Rain Program, please refer to indicator report #4176 Air Quality.

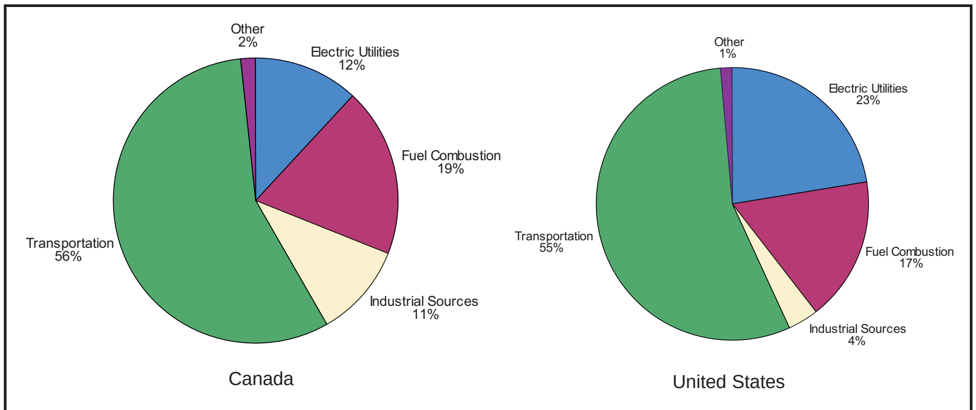

Figure 2. Sources of Nitrogen Oxides Emissions in Canada and the U.S. (1999)
Source: Figure 6 of Canada - United States Air Quality Agreement: 2002 Progress Report. http://www.epa.gov/airmarkets/usca/airus02.pdf and Environment Canada 1999 Pollutant Release Inventory Data and U.S. Environmental Protection Agency 1999 National Emissions Inventory Documentation and Data

Sulfur Dioxide and Nitrous Oxides Emissions Reductions

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

Canada is committed to reducing acid rain in its south-eastern region to levels below those that cause harm to ecosystems – a level commonly called the "critical load" - while keeping other areas of the country (where acid rain effects have not been observed) clean. In 2000, total SO_2 emissions in Canada were 2.4 million tonnes, which is about 23% below the national cap of 3.2 million tonnes reiterated under Annex 1 (the Acid Rain Annex) of the Air Quality Agreement. Emissions in 2000 also represent a 50% reduction from 1980 emission levels. The seven easternmost provinces' 1.6 million tonnes of emissions in 2000 were 29% below the eastern Canada cap of 2.3 million tonnes reiterated under the Acid Rain Annex.

In 2002, all participating sources of the U.S. Environmental Protection Agency's Acid Rain Program (Phase I & II) achieved a total reduction in SO_2 emissions of about 35% from 1990 levels, and 41% from 1980 levels. The Acid Rain Program now affects approximately 3,000 fossil-fuel power plant units. These units reduced their SO_2 emissions to 10.19 million tons in 2002, about 4% lower than 2001 emissions. Full implementation of the program in 2010 will result in a permanent national emissions cap of 8.95 million tons, representing about a 50% reduction from 1980 levels.

Figure 3 illustrates the trends in SO_2 emission levels in Canada and the United States measured from 1980 to 2000 and predicted through 2010. Overall, a 38% reduction in SO_2 emissions is projected in Canada and the United States from 1980 to 2010. In the U.S., the reductions are mainly due to controls on electric utili-

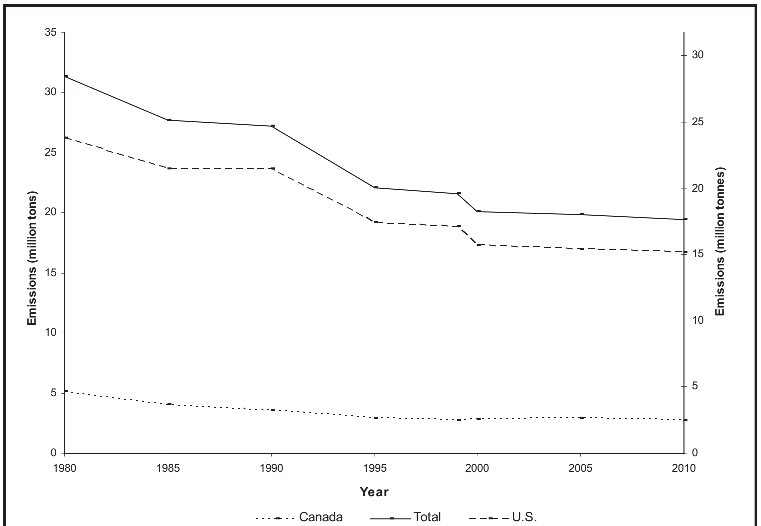

Figure 3. Canada-U.S. sulfur dioxide emissions, 1980-2010
Source: Figure 3 of Canada - United States Air Quality Agreement: 2002 Progress Report. http://www.epa.gov/airmarkets/usca/airus02.pdf and U.S. Environmental Protection Agency. Projection year emissions data. http://www.epa.gov/otaq/models/hd2007/r00020.pdf

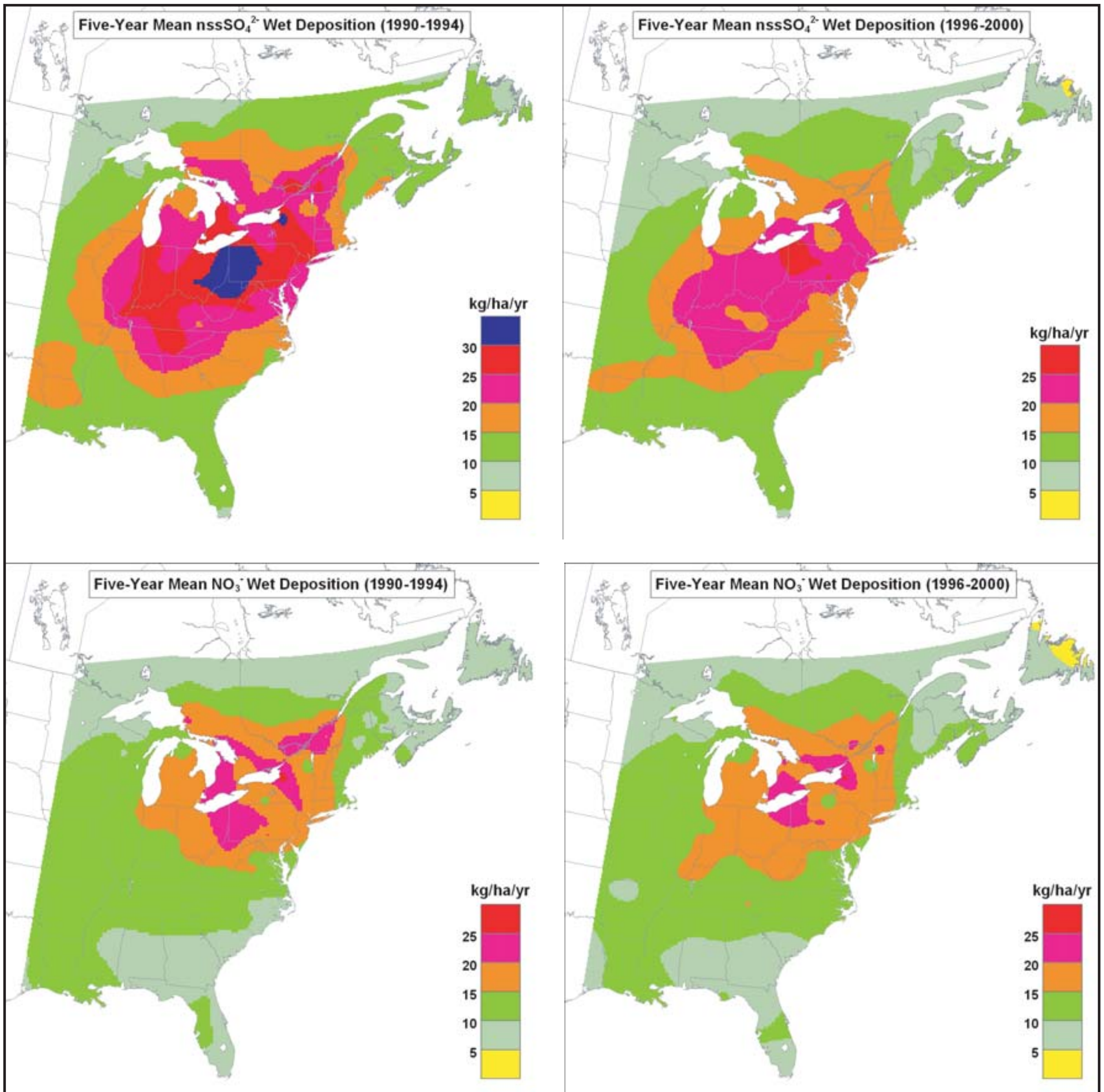

Figure 4. Five-year mean patterns of wet non-sea-salt-sulfate ($nssSO_4^{2-}$) and wet nitrate deposition for the periods 1990-1994 and 1996-2000.
Source: Figures 9 through 12 of Canada - United States Air Quality Agreement: 2002 Progress Report. http://www.epa.gov/airmarkets/usca/airus02.pdf, and Jeffries, D.S., T.G., Brydges, P.J. Dillion and W. Keller. 2003. Monitoring the results of Canada/U.S.A. acid rain control programs: some lake responses. J. of Environmental Monitoring and Assessment. 88:3-20

ties under the Acid Rain Program and the desulphurization of diesel fuel under Section 214 of the 1990 Clean Air Act Amendments. In Canada, reductions of SO_2 are mainly attributed to reductions from the non-ferrous mining and smelting sector, and electric utilities as part of the 1985 Eastern Canada Acid Rain Program that was completed in 1994. Further SO_2 reductions will be achieved through the implementation of the Canada-Wide Acid Rain Strategy.

Figure 4 compares wet sulfate deposition (kilograms sulfate per hectare per year) over eastern North America before and after the 1995 Acid Rain Program Phase I emission reductions to assess whether the emission decreases had an impact on large-scale wet deposition. The five-year average sulfate wet deposition pattern for the years 1996-2000 is considerably reduced from that for the five-year period prior to the Phase I emission reductions (1990-1994). For example, the large area that received 25 to 30 kg/ha/yr of sulfate wet deposition in the 1990-1994 period had almost disappeared in the1996-2000 period. The shrinkage of the wet deposition pattern between the two periods strongly suggests that the Phase I emission reductions were successful at reducing the sulfate wet deposition over a large section of eastern North America. Monitoring data from 2000 through 2002 indicate that wet sulfate deposition continued to decrease, probably as a result of Phase II of the Acid Rain Program. However, if SO_2 emissions remain relatively constant after the year 2000, as predicted (Figure 3), it is unlikely that sulfate deposition will change considerably in the coming decade. Sulfate deposition models predict that in 2010, following implementation of the Phase II acid rain program, critical loads for aquatic ecosystems in eastern Canada will still be exceeded over an area of approximately 800,000 km^2.

A somewhat different story occurs for nitrate wet deposition.

The spatial patterns shown in Figure 4 are approximately the same before and after the Phase I emission reductions. This suggests that the minimal reductions in NO_x emissions after Phase I resulted in minimal changes to nitrate wet deposition over eastern North America.

Pressures

As the human population within and outside the basin continues to grow, there will be increasing demands on electrical utility companies and natural resources and increasing numbers of motor vehicles. Considering this, reducing nitrogen deposition is becoming more and more important, as its contribution to acidification may soon outweigh the benefits gained from reductions in sulfur dioxide emissions.

Management Implications

The effects of acid rain can be seen far from the source of SO_2 and NO_x generation, so the governments of Canada and the United States are working together to reduce acid emissions. The 1991 Canada - United States Air Quality Agreement addresses transboundary pollution. To date, this agreement has focused on acidifying pollutants and significant steps have been made in the reduction of SO_2 emissions. However, further progress in the reduction of acidifying pollutants, including NO_x, is required.

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

The 1998 Canada-wide Acid Rain Strategy for Post-2000 provides a framework for further actions, such as establishing new SO_2 emission reduction targets in Ontario, Quebec, New Brunswick and Nova Scotia. In fulfillment of the Strategy, each of these provinces has announced a 50% reduction from its existing emissions cap. Quebec, New Brunswick and Nova Scotia are committed to achieving their caps by 2010, while Ontario committed to meet its new cap by 2015.

Since the last State of the Lakes Ecosystem Conference (SOLEC) report, there has been increasing interest in both the public and private sector in a multi-pollutant approach to reducing air pollution. On March 10, 2005, the U.S. Environmental Protection Agency (USEPA) issued the Clean Air Interstate Rule (CAIR), a rule that will achieve the largest reduction in air pollution in more than a decade. Through a cap-and-trade approach, CAIR will permanently cap emissions of SO_2 and NO_x across 28 eastern states and the District of Columbia. When fully implemented, CAIR is expected to reduce SO_2 emissions in these states by 73% and NO_x emissions by 61% from 2003 levels.

The Clear Skies Initiative, originally proposed by U.S. President George W. Bush in February 2002, would require a similar level of SO_2 and NO_x reductions as CAIR. Because Clear Skies would be enacted through legislation rather than regulation, it would be a more efficient, long-term mechanism to achieve multi-pollutant reductions on a national scale. The USEPA is committed to working with Congress to pass this legislation. However, if Clear Skies is not passed, CAIR still remains in effect.

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Kerri Timoffee, Manager, Acid Rain Program, Environment Canada, Gatineau, QC; and
Todd Nettesheim, Great Lakes National Program Office, United States Environmental Protection Agency, Chicago, IL.

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Authors' Commentary

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

Last Updated

State of the Great Lakes 2005

Non-native Species – Aquatic
Indicator #9002

Overall Assessment

Status: **Poor**
Trend: **Deteriorating**
Primary Factors Determining Status and Trend: **NIS continue to be discovered in the Great Lakes. Negative impacts of established invaders persist and new negative impacts are becoming evident**

Lake-by-Lake Assessment

Lake Superior

Status: Fair
Trend: Unchanging
Primary Factors Determining Status and Trend: Lake Superior is the site of most ballast water discharge in the Great Lakes, but supports relatively few NIS. This is due at least in part to less hospitable environmental conditions.

Lake Michigan

Status: Poor
Trend: Deteriorating
Primary Factors Determining Status and Trend: Established invaders continue to exert negative impacts on native species. *Diporeia* populations are declining.

Lake Huron

Status: Poor
Trend: Deteriorating
Primary Factors Determining Status and Trend: Established invaders continue to exert negative impacts on native species. *Diporeia* populations are declining.

Lake Erie

Status: Poor
Trend: Deteriorating
Primary Factors Determining Status and Trend: Established invaders continue to exert negative impacts on native species. A possible link exists between waterfowl deaths due to botulism and established NIS (round goby and dreissenid mussels)

Lake Ontario

Status: Poor
Trend: Deteriorating
Primary Factors Determining Status and Trend: Native *Diporeia* populations are declining in association with quagga mussel expansion. Condition and growth of lake whitefish, whose primary food source is *Diporeia*, are declining. A possible link exists between waterfowl deaths due to botulism and established NIS (round goby and dreissenid mussels).

Purpose
•To assess the presence, number and distribution of nonindigenous species (NIS) in the Laurentian Great Lakes; and
•To aid in the assessment of the status of biotic communities, because nonindigenous species can alter both the structure and function of ecosystems.

Ecosystem Objective
The goal of the U.S. and Canada Great Lakes Water Quality Agreement is, in part, to restore and maintain the biological integrity of the waters of the Great Lakes ecosystem. Minimally, extinctions and unauthorized introductions must be prevented to maintain biological integrity.

State of the Ecosystem
Background
Nearly 10% of NIS introduced to the Great Lakes have had significant impacts on ecosystem health, a percentage consistent with findings in the United Kingdom (Williamson and Brown 1986) and in the Hudson River of North America (Mills *et al*. 1997). In the Great Lakes, transoceanic ships are the primary invasion vector. Other vectors, such as canals and private sector activities, however, are also utilized by NIS with potential to harm biological integrity.

Status of NIS
Human activities associated with transoceanic shipping are responsible for over one-third of NIS introductions to the Great Lakes (Figure 1). Total numbers of NIS introduced and established in the Great Lakes have increased steadily since the 1830s (Figure 2a). Numbers of ship-introduced NIS, however, have increased exponentially during the same time period (Figure 2b). Release of contaminated ballast water by transoceanic ships has been implicated in over 70% of faunal NIS introductions to the Great Lakes since the opening of the St. Lawrence Seaway in 1959 (Grigorovich *et al*. 2003).

During the 1980s, the importance of ship ballast water as a vector for NIS introductions was recognized, finally prompting ballast management measures in the Great Lakes. In the wake of Eurasian ruffe and zebra mussel introductions, Canada introduced voluntary ballast exchange guidelines in 1989 for ships declaring "ballast on board" (BOB) following transoceanic voyages, as recommended by the Great Lakes Fishery Commission and the International Joint Commission. In 1990, the United States Congress passed the Nonindigenous Aquatic Nuisance Prevention and Control Act, producing the Great Lakes' first ballast exchange and management regulations in May of 1993. The National Invasive Species Act (NISA) followed in 1996, but this act expired in 2002. A stronger version of NISA entitled the Nonindigneous Aquatic Invasive Species Act has been drafted and awaits Congressional reauthorization.

Contrary to expectations, the reported invasion rate has increased following initiation of voluntary guidelines in 1989 and mandated regulations in 1993 (Grigorovich *et al*. 2003, Holeck *et al*. 2004). However, >90% of transoceanic ships that entered the Great Lakes during the 1990s declared "no ballast on board" (NOBOB, Colautti *et al*. 2003; Grigorovich *et al*. 2003; Holeck *et al*. 2004) (Figure 3) and were not required to exchange ballast, although their tanks contained residual sediments and water that would be discharged in the Great Lakes. Recent studies suggest that the Great Lakes may vary in vulnerability to invasion in space and time. Lake Superior receives a disproportionate number of discharges by both BOB and NOBOB ships, yet it has sustained surprisingly few initial invasions (Figure 4); conversely, the waters connecting lakes Huron and Erie are an invasion 'hotspot' despite receiving disproportionately few ballast discharges (Grigorovich *et al*. 2003). Ricciardi (2001) suggests that some invaders (such as *Dreissena* spp.) may facilitate the introduction of coevolved species such as round goby and the amphipod *Echinogammarus*.

Other vectors, including canals and the private sector, continue to deliver NIS to the Great Lakes and may increase in relative importance in the future. Silver and bighead carp escapees from southern U.S. fish farms have been sighted below an electric dispersal barrier in the Chicago Sanitary and Ship Canal, which connects the Mississippi River and Lake Michigan. The prototype barrier was activated in April 2002, to block the transmigration of species between the Mississippi River system and the Great Lakes basin. The U.S. Army Corps of Engineers (partnered by the State of Illinois) completed construction of a second, permanent barrier in 2005.

Second only to shipping, unauthorized release, transfer, and escape have introduced NIS into the Great Lakes. Of particular concern are private sector activities related to aquaria, garden ponds, baitfish, and live food fish markets. For example, nearly a million Asian carp, including bighead and black carp, are sold annually at fish markets within the Great Lakes basin. Until recently, most of these fish were sold live. All eight Great Lakes states and the province of Ontario now have some restriction on the sale of live Asian carp. Enforcement of many private transactions, however, remains a challenge. The U.S. Fish and Wildlife Service is considering listing several Asian carp as nuisance species under the Lacey Act, which would prohibit interstate transport. Finally, there are currently numerous shortcomings in legal safeguards relating to commerce in exotic live fish as identified by Alexander (2003) in Great Lakes and Mississippi River states, Quebec, and Ontario. These include: express and de facto exemptions for the aquarium pet trade; de facto exemptions for the live food fish trade; inability to proactively enforce import bans; lack of inspections at aquaculture facilities; allowing aquaculture in public waters; inadequate triploidy (sterilization) requirements; failure to regulate species of concern, e.g., Asian carp; regulation through "dirty lists" only, e.g., banning known nuisance species; and failure to regulate transportation.

Pressures

NIS have invaded the Great Lakes basin from regions around the globe (Figure54), and increasing world trade and travel will elevate the risk that additional species (Table 1) will continue to gain access to the Great Lakes. Existing connections between the Great Lakes watershed and systems outside the watershed, such as the Chicago Sanitary and Ship Canal, and growth of industries such as aquaculture, live food markets, and aquarium retail stores will also increase the risk that NIS will be introduced.

Changes in water quality, global climate change, and previous NIS introductions also may make the Great Lakes more hospitable for the arrival of new invaders. Evidence indicates that newly invading species may benefit from the presence of previously established invaders. That is, the presence of one NIS may facilitate the establishment of another (Ricciardi 2001). For example, round goby and *Echinogammarus* have benefited from previously established zebra and quagga mussels. In effect, dreissenids have set the stage to increase the number of successful invasions, particularly those of co-evolved species in the Ponto-Caspian assemblage.

Management Implications

Researchers are seeking to better understand links between vectors and donor regions, the receptivity of the Great Lakes ecosystem, and the biology of new invaders in order to make recommendations to reduce the risk of future invasion. To protect the biological integrity of the Great Lakes, it is essential to closely monitor routes of entry for NIS, to introduce effective safeguards, and to quickly adjust safeguards as needed. Invasion rate may increase if positive interactions involving established NIS or native species facilitate entry of new NIS. Ricciardi (2001) suggested that such a scenario of "invasional meltdown" is occurring in the Great Lakes, although Simberloff (2006) cautioned that most of these cases have not been proven.
To be effective in preventing new invasions, management strategies must focus on linkages between NIS, vectors, and donor and receiving regions. Without measures that effectively eliminate or minimize the role of ship-borne and other, emerging vectors, we can expect the number of NIS in the Great Lakes to continue to rise, with an associated loss of native biodiversity and an increase in unpredicted ecological disruptions.

Comments from the author(s)

Lake by lake assessment should include Lake St. Clair and connecting channels (Detroit River, St. Clair River). Species first discovered in these waters were assigned to Lake Erie for the purposes of this report.

Acknowledgments

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Figure 5. Regions of origin for aquatic NIS established in the Great Lakes basin since the 1830s. Source: Mills *et al*. 1993; Ricciardi 2001; Grigorovich *et al*. 2003; Ricciardi 2006

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Lake/Basin of First Discovery	**Fauna**	**Flora**	
Unknown/Widespread	33	9	
Multiple	4	1	
Ontario	24	33	
Erie	16	21	
Huron	4	3	
Michigan	11	16	
Superior	3	4	
	95	**87**	**182**

Table 1. Nonindigenous species predicted to have a high-risk of introduction to the Great Lakes.
Source: Ricciardi and Rasmussen 1998; Kolar and Lodge 2002; Grigorovich *et al*. 2003; Stokstad 2003; Rixon *et al*. 2004

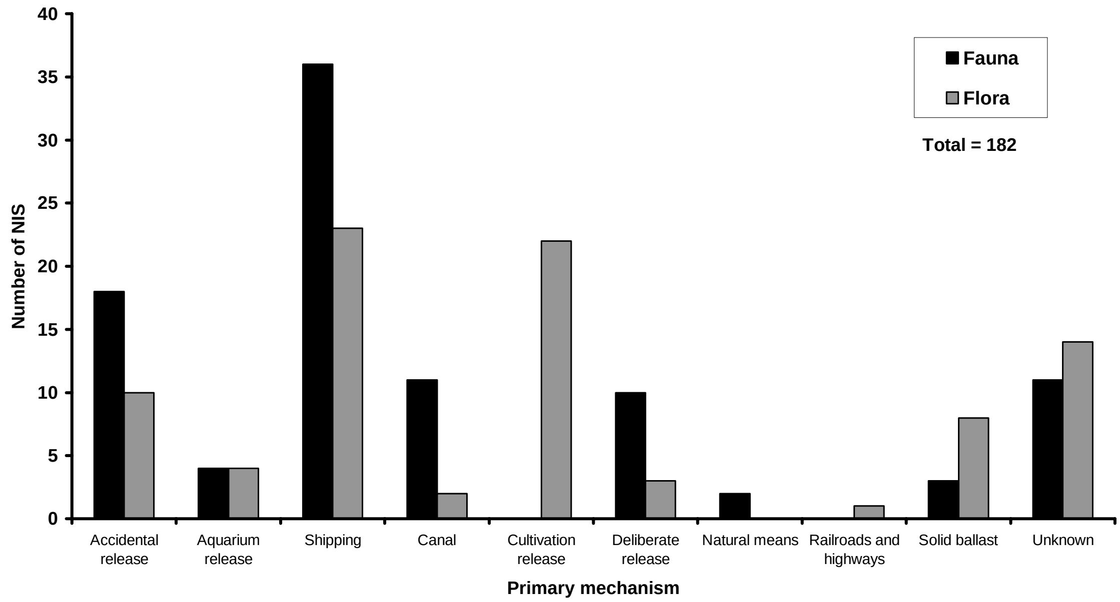

Figure 1. Release mechanisms for aquatic nonindigenous (NIS) established in the Great Lakes basin since the 1830s.
Source: Mills *et al*. 1993; Ricciardi 2001; Grigorovich *et al*. 2003; Ricciardi 2006

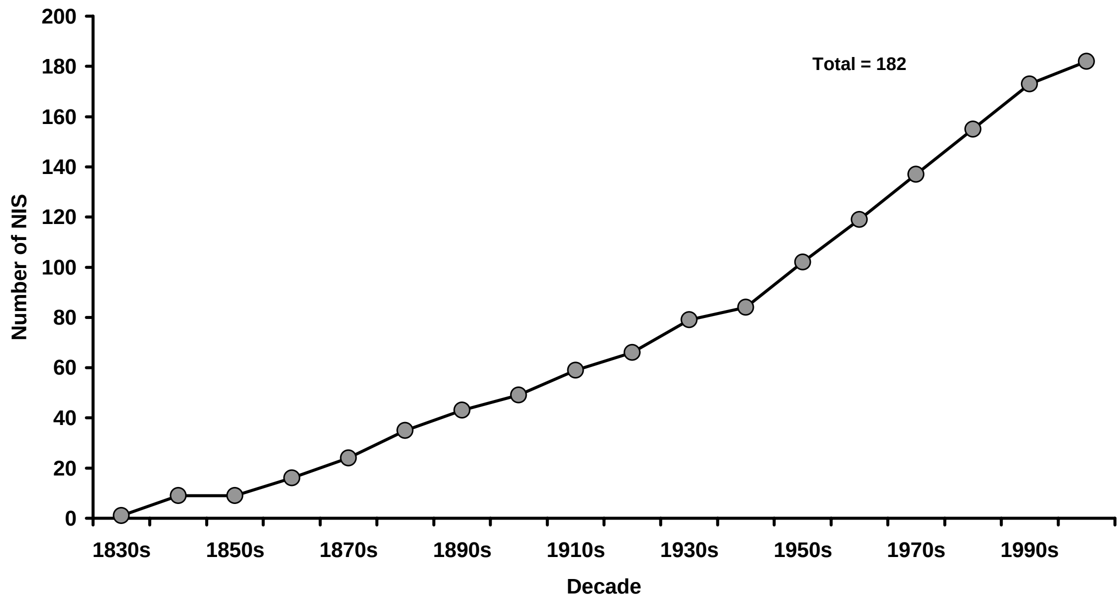

Figure 2a. Cumulative number of aquatic nonindigenous (NIS) established in the Great Lakes basin since the 1830s attributed to all vectors.
Source: Mills *et al*. 1993; Ricciardi 2001; Grigorovich *et al*. 2003; Ricciardi 2006

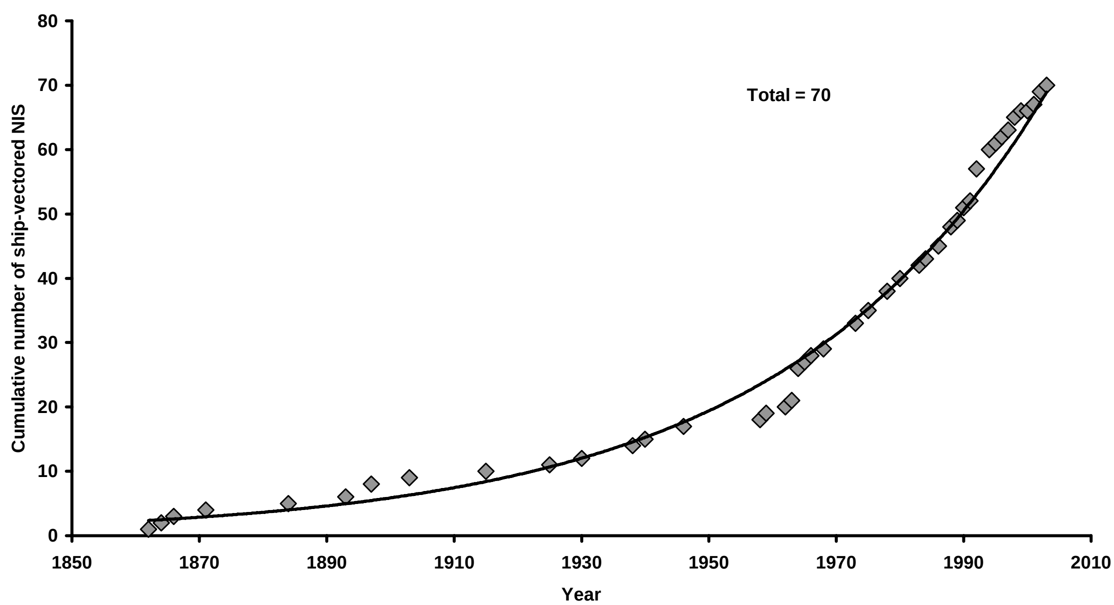

Figure 2b. Cumulative number of aquatic nonindigenous (NIS) established in the Great Lakes basin since the 1830s attributed to the ship vector.
Source: Mills *et al*. 1993; Ricciardi 2001; Grigorovich *et al*. 2003; Ricciardi 2006

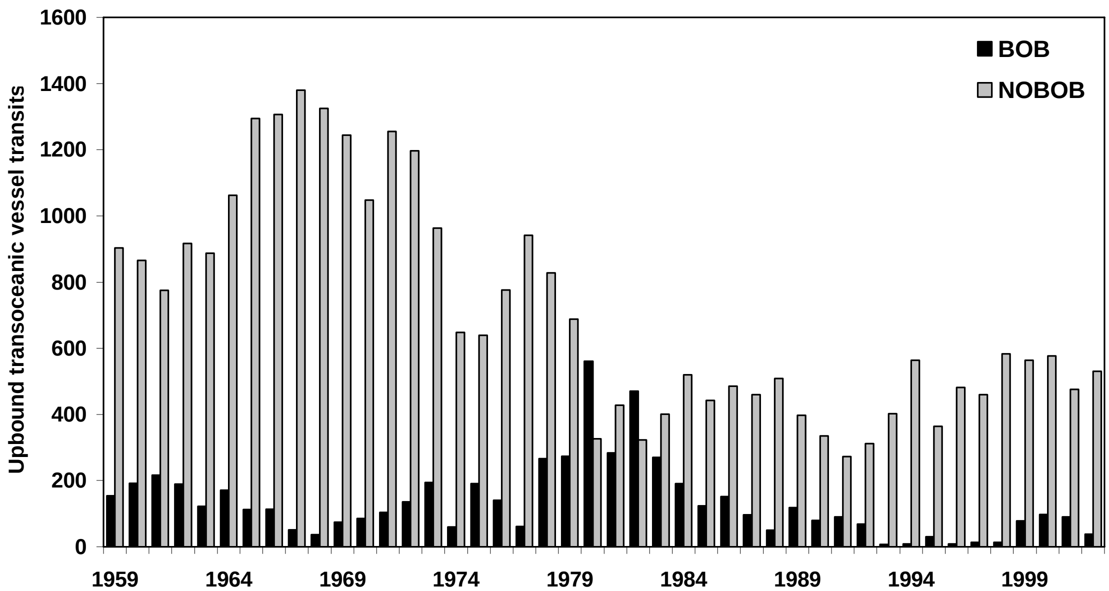

Figure 3. Numbers of upbound transoceanic vessels entering the Great Lakes from 1959 to 2002. Source: Colautti *et al*. 2003; Grigorovich *et al*. 2003; Holeck *et al*. 2004

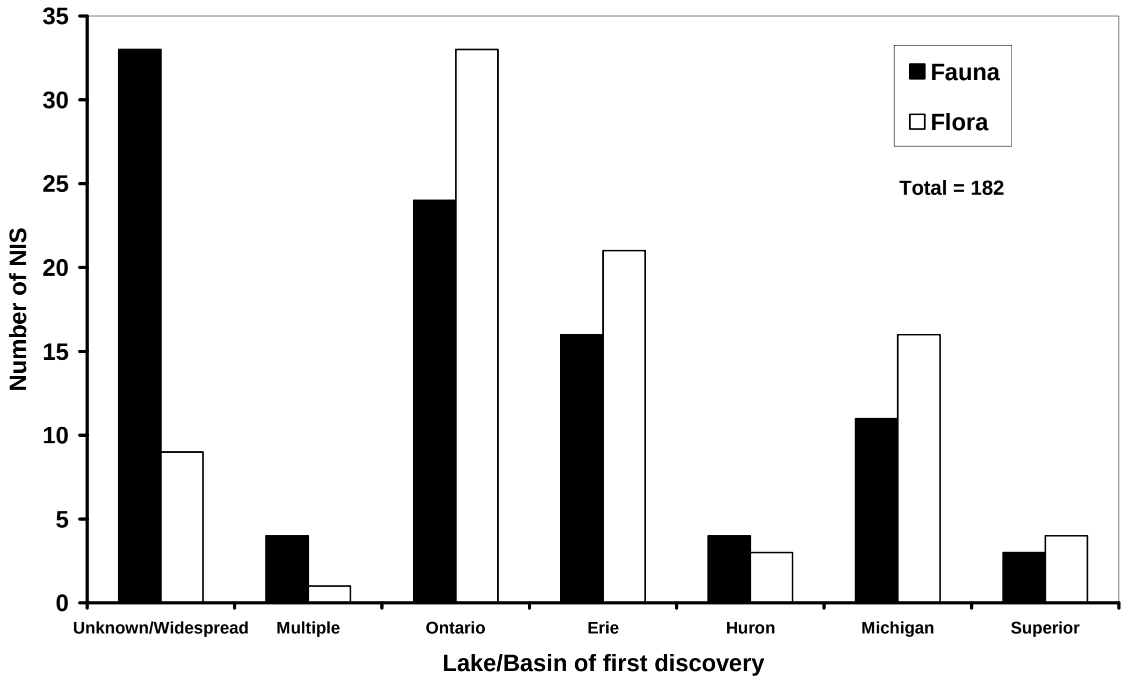

Figure 4. Lake of first discovery for NIS established in the Great Lakes basin since the 1830s. Discoveries in connecting waters between Lakes Huron, Erie and Ontario were assigned to the downstream lake.
Source: Grigorovich *et al*. 2003

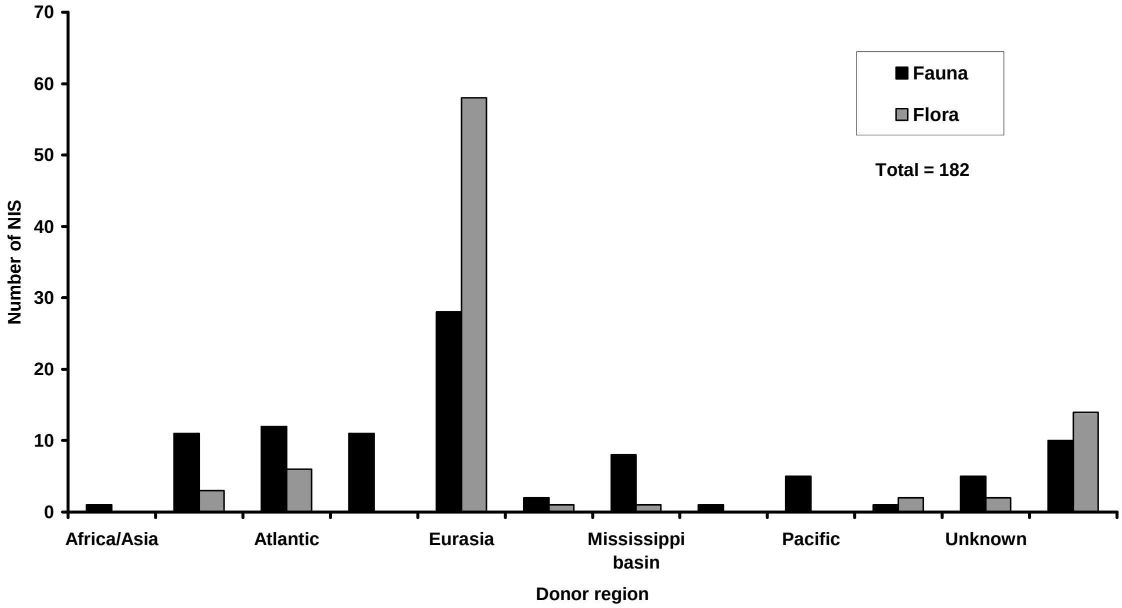

Figure 5. Regions of origin for aquatic NIS established in the Great Lakes basin since the 1830s. Source: Mills *et al*. 1993; Ricciardi 2001; Grigorovich *et al*. 2003; Ricciardi 2006

Non-native Species - Terrestrial
Indicator #9002

Overall Assessment

Status: **Mixed**
Trend: **Deteriorating/Undetermined**
Primary Factors Determining Status and Trend: **Terrestrial Non-indigenous species are pervasive in the Great Lakes basin. Although not all introductions have an adverse effect on native habitats, those that do pose a considerable ecological, social, and economic burden. Historically, the Great Lakes Basin has proven to be particularly vulnerable to non-indigenous species, mainly due to the high volume of transboundary movement of goods and people, population, and industrialization. Improved monitoring of non-indigenous species is needed to adequately assess the status, trends, and impacts of non-indigenous species in the region.**

Lake-by-Lake Assessment

Lake Superior

Status: Not Assessed
Trend: Undetermined
Primary Factors Determining Status and Trend: Not available at this time.

Lake Michigan

Status: Not Assessed
Trend: Undetermined
Primary Factors Determining Status and Trend: Not available at this time.

Lake Huron

Status: Not Assessed
Trend: Undetermined
Primary Factors Determining Status and Trend: Not available at this time.

Lake Erie

Status: Not Assessed
Trend: Undetermined
Primary Factors Determining Status and Trend: Not available at this time.

Lake Ontario

Status:	Not Assessed
Trend:	Undetermined
Primary Factors Determining Status and Trend	Not available at this time.

Purpose

- To evaluate the presence, number, and impact of terrestrial non-indigenous species in the Great Lakes Basin.
- To assess the biological integrity of the Great Lakes Basin ecosystems.

Ecosystem Objective

The ultimate goal of this indicator is to limit, or prevent, the unauthorized introduction of non-indigenous species, and to minimize their adverse affect in the Great Lakes Basin. Such actions would assist in accomplishing one of the major objectives of U.S. and Canada Great Lakes Water Quality Agreement, which is to restore and maintain the biological integrity of the waters of the Great Lakes ecosystem.

State of the Ecosystem

Globalization, i.e. the movement of people and goods, has led to a dramatic increase in the number of terrestrial non-indigenous species (NIS) that are transported from one country to another. As a result of its high population density and high-volume transportation of goods, the Great Lakes Basin (GLB) is very susceptible to the introduction of such invaders. Figure 1 depicts this steady increase in the number of terrestrial NIS introduced into the GLB and the rate at which this has occurred, beginning in the 1900s. In addition, the degradation, fragmentation, and loss of native ecosystems have also made this region more vulnerable to these invaders, enabling them to become invasive (non-indigenous species or strains that become established in native communities or wild areas and replace native species). As such, the introduction of NIS is considered to be one of the greatest threats to the biodiversity and natural resources of this region, second only to habitat destruction.

Monitoring of NIS is largely locally based, as a region-wide standard has yet to be established. As a result, the data that is generated comes from a variety of agencies and organizations throughout the region, thus providing some difficulty when attempting to assess the overall presence and impact these species are having on the region. Information provided by the World Wildlife Fund of Canada indicates that there are 157 exotic plants and animals located within the GLB, which includes: 95 vascular plants, 11 insects, 6 plant diseases, 4 mammals, 2 birds, 2 animal diseases, 1 reptile, and 1 amphibian. However, the Invasive Plant Association of Wisconsin has identifies 116 non-native plants within the state, while over one hundred plants have been introduced into the Chicago region (Chicago Botanic Garden). Even though these figures are greater then the one provided by the WWF of Canada, they do not compare to the over 900 non-native plants that have been identified within the state of Michigan by the Michigan Invasive Plant Council.

The impact NIS have on the areas in which they are introduced can vary greatly, ranging from little or no affect to dramatically altering the native ecological community. Figure 2 shows the degree to which each taxonomic group has had an impact on the ecoregion. The WWF of Canada has listed 29 species, 19 of which are vascular plants, as having a “severe impact” on native biodiversity. These species, which were generally introduced for medicinal or ornamental purposes, have become problematic as they continue to thrive due to the fact that they are well adapted to a broad range of habitats, have no native predators, and are often able to reproduce at a rapid rate. Common buckthorn, garlic mustard, honeysuckle, purple loosestrife, and reed canary grass are several examples of highly invasive plant species, while the Asian longhorn beetle, Dutch elm disease, emerald ash borer, leafy spurge, and the West Nile virus are other terrestrial invaders that have had a significant impact of the GLB.

One type of terrestrial non-native species not covered in this report is genetically modified organisms (GMOs). Although GMOs are typically cultivated for human uses and benefits, the problem arises when pollen is moved from its intended site (often by wind or pollinator species) and transfers genetically engineered traits, such as herbicide resistance and pest resistance, to wild plants. This outward gene flow into natural habitats has the potential to significantly alter ecosystems and create scenarios that would pose enormous dilemmas for farmers. Both Canada and the U.S. are major producers of genetically modified organisms (GMOs). Although GMO crops are monitored for outward gene flow, no centralized database describing the number of GMO species, or land area covered by GMOs in the Great Lakes Basin currently exists.

There are currently numerous policies, laws and regulations within the GLB that address NIS; however, similar to NIS monitoring, they originate from state, provincial and federal administrations and thus have similar obstacles associated with them. As such, strict enforcement of these laws, in addition to continuous region-wide mitigation, eradication and management of NIS is needed in order to maintain the ecological integrity of the GLB.

Pressures

The growing transboundary movement of goods and people has heightened the need to prevent and manage terrestrial NIS. Most cases of invasiveness can be linked to the intended or unintended consequences of economic activities (Perrings, et al., 2002). For this reason, the GLB has been, and will continue to be, a hot bed of introductions, unless preventive measures are enforced. The growth in population, threats, recreation and tourism all contribute to the number of NIS affecting the region. Additionally, factors such as the increase in development and human activity, previous introductions and climate change have elevated the levels of vulnerability. Because this issue has social, ecological, and economic dimensions it can be assumed that the pressure of NIS will persist unless it is addressed on all three fronts.

Management Implications

Since the early 1800s, biological invasions have compromised the ecological integrity of the GLB. Despite an elevated awareness of the issue and efforts to prevent and manage NIS in the Great Lakes, the area remains highly vulnerable to both intentional and non-intentional introductions. Political and social motivation to address this issue is driven not only by the effects on the structure and function of regional ecosystems, but also by the cumulative economic impact of invaders, i.e. threats to food supplies and human health.

Managers of terrestrial NIS in the GLB recognize that successful management strategies must involve collaboration across federal, provincial and state governments, in addition to non-governmental organizations. Furthermore, improved integration, coordination and development of inventories, mapping, and mitigation of terrestrial invasive species can be used to adapt future strategies and examine trends in terrestrial NIS at a basin-wide scale. Although current monitoring programs in Canada are fragmented at best, a number of initiatives involving broad-stakeholder participation and government collaboration are being developed to determine future priorities. This information will be applied to risk analysis, predictive science, modeling, improved technology for prevention and management of NIS, legislation and regulations, education and outreach, and international co-operation to encompass the multi-faceted aspect of this ecological, social, and economic issue.

Comments from the author(s)
Currently, there is no central monitoring site for terrestrial NIS in Canada. In 1997 the Canadian Botanical Conservation Network put together a database on invasive plant species for Canada, but the information has not since been updated. In 2000 the World Wildlife Fund of Canada amassed information about 150 known NIS in Canada in a centralized database, based on books, journal articles, websites, and consultation with experts. The author of the chapter acknowledges that a lack of centralized data was a limitation of the project. The information contained in this indicator is based on the WWF-C database and has been updated with several more recent insect invaders present in the GLB.

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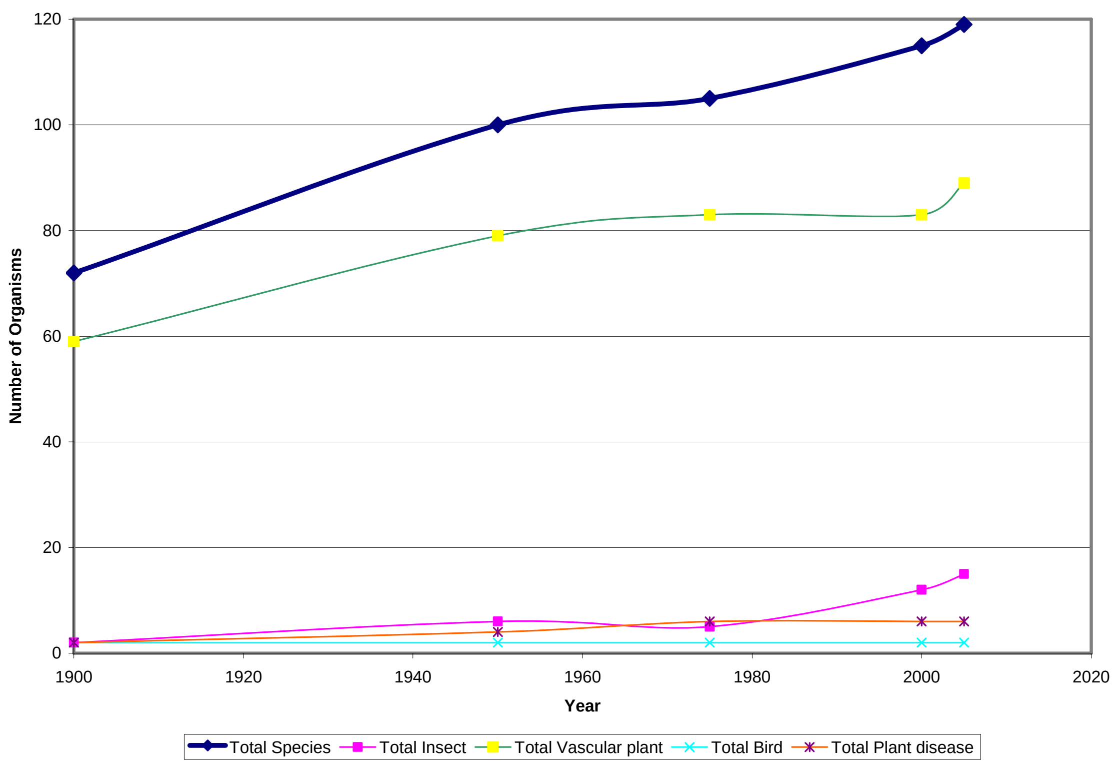

Figure 1. A timeline of terrestrial introduction in the Great Lakes Basin by taxonomic group. Data source: World Wildlife Fund-Canada's Exotic Species Database, and the Canadian Food Inspection Agency.

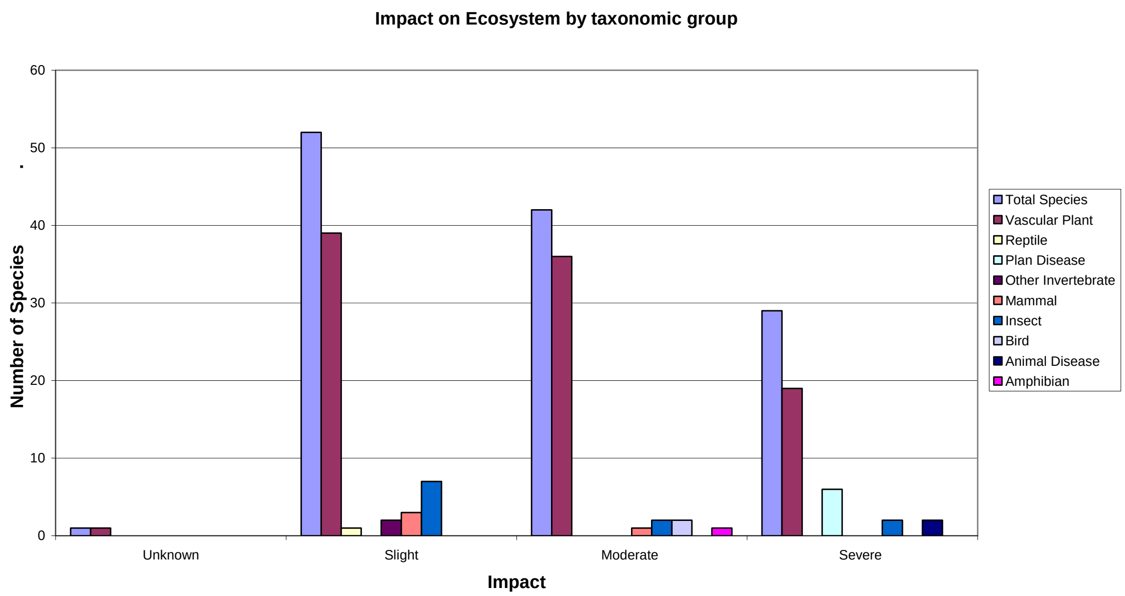

Figure 2. Estimated impact of 124 known terrestrial NIS in the Great Lakes Basin by taxonomic group.
Data source: World Wildlife Fund-Canada's Exotic Species Database.

List of indicators by category

Contamination indicators

Status, Trend	Indicator Title (indicator number)	Year
Open Lake: Mixed, Undetermined Nearshore: Poor, Undetermined	Phosphorus Concentrations and Loadings (111)	2006
Mixed, Improving SU, HU, ER, ON: mixed, improving MI: NA	Contaminants in Young-of-the-Year Spottail Shiners (114)	2006
Mixed, Improving SU: good, improving MI, HU, ER: mixed, improving ON: poor, improving	Contaminants in Colonial Nesting Waterbirds (115)	2006
Mixed, Improving/Unchanging	Atmospheric Deposition of Toxic Chemicals (117)	2006
Mixed, Undetermined SU, MI, HU: fair, undetermined ER, ON: mixed, undetermined	Toxic Chemical Concentrations in Offshore Waters (118)	2006
Mixed, Improving/Undetermined	Concentrations of Contaminants in Sediment Cores (119)	2006
Mixed, Improving SU, MI, HU, ER, ON: fair, improving	Contaminants in Whole Fish (121)	2006
Poor, Unchanging SU, MI, HU: undetermined ER, ON: poor, unchanging	External Anomaly Prevalence Index for Nearshore Fish (124)	2006
Good, Unchanging	Drinking Water Quality (4175)	2006
Mixed, Undetermined	Biologic Markers of Human Exposure to Persistent Chemicals (4177)	2006
Mixed, Improving	Contaminants in Sport Fish (4201)	2006
Mixed, Improving	Air Quality (4202)	2006
Mixed, Undetermined SU, MI, HU: undetermined ER, ON: mixed, undetermined	Contaminants in Snapping Turtle Eggs (4506)	2006
Undetermined	Nutrient Management Plans (7061)	2005
Progress Report	Wastewater Treatment and Pollution (7065)	2006
Mixed, Improving	Contaminants Affecting Productivity of Bald Eagles (8135)	2005
Mixed, Undetermined	Population Monitoring and Contaminants Affecting the American Otter (8147)	2003
Mixed, Improving	Acid Rain (9000)	2005

Biotic Communities indicators

Status, Trend	Indicator Title (indicator number)	Year
Mixed, Improving SU: fair, improving MI: mixed, slightly improving HU: fair, improving ER: good, improving ON: mixed, unchanging	Salmon and Trout (8)	**2006**
Fair, Unchanging	Walleye (9)	**2006**
Mixed, Deteriorating SU: mixed, improving MI, HU, ER, ON: mixed, deteriorating	Preyfish Populations (17)	**2006**
Undetermined	Native Freshwater Mussels (68)	**2005**
Mixed, Unchanging SU: good, improving MI: poor, declining HU: mixed, improving ER: mixed, unchanging ON: mixed, declining	Lake Trout (93)	**2006**
Mixed, Unchanging/Deteriorating SU: good, unchanging MI, ER: mixed, unchanging/deteriorating HU, ON: mixed, unchanging	Benthos Diversity and Abundance - **Aquatic Oligochaete Communities** (104)	**2006**
Mixed, Undetermined	Phytoplankton Populations (109)	**2003**
Mixed, Improving SU: good, improving MI, HU, ER: mixed, improving ON: poor, improving	Contaminants in Colonial Nesting Waterbirds (115)	**2006**
Mixed, Undetermined SU: good, unchanging MI, HU, ER, ON: undetermined	Zooplankton Populations (116)	**2006**
Mixed, Improving SU, MI, HU: poor, undetermined ER: good/mixed, improving/mixed ON: undetermined	*Hexagenia* (122)	**2006**
Mixed, Deteriorating SU: mixed, unchanging MI, HU, ER, ON: poor, deteriorating	Abundances of the Benthic Amphipod *Diporeia* spp. (123)	**2006**
Mixed, Improving SU, MI, HU: mixed, improving/undetermined ER: poor, undetermined ON: mixed, improving	Status of Lake Sturgeon in the Great Lakes (125)	**2006**
Progress Report	Coastal Wetland Invertebrate Community Health (4501)	**2005**
Undetermined	Coastal Wetland Fish Community Health (4502)	**2006**
Mixed, Deteriorating SU: undetermined MI: poor, unchanging HU, ER: mixed, deteriorating ON: mixed, unchanging	Wetland-Dependent Amphibian Diversity and Abundance (4504)	**2006**

Biotic Communities indicators (continued)

Mixed, Deteriorating SU: undetermined MI, ER, ON: mixed, deteriorating HU: poor, deteriorating	Wetland-Dependent Bird Diversity and Abundance (4507)	**2006**
Mixed, Undetermined SU: good, unchanging MI, ER: mixed, unchanging HU: mixed, deteriorating ON: poor, unchanging	Coastal Wetland Plant Community Health (4862)	**2006**
Undetermined	Groundwater Dependant Plant and Animal Communities (7103)	**2005**
Mixed, Improving	Contaminants Affecting Productivity of Bald Eagles (8135)	**2005**
Mixed, Undetermined	Population Monitoring and Contaminants Affecting the American Otter (8147)	**2003**
Mixed, Undetermined	Forest Lands-Conservation of Biological Diversity (8500)	**2006**

Invasive Species indicators

Good/Fair, Improving	Sea Lamprey (18)	**2005**
Poor, Deteriorating SU: fair, unchanging MI, HU, ER, ON: poor, deteriorating	Non-native Species—Aquatic (9002)	**2006**
Mixed, Deteriorating/Undetermined	Non-native Species—Terrestrial (9002)	**2006**

Coastal Zones indicators

Status, Trend	Indicator Title (indicator number)	Year
Progress Report	Coastal Wetland Invertebrate Community Health (4501)	2006
Undetermined	Coastal Wetland Fish Community Health (4502)	2006
Mixed, Deteriorating SU: undetermined MI: poor, unchanging HU, ER: mixed, deteriorating ON: mixed, unchanging	Wetland-dependent Amphibian Diversity and Abundance (4504)	2006
Mixed, Undetermined SU, MI, HU: undetermined ER, ON: mixed, undetermined	Contaminants in Snapping Turtle Eggs (4506)	2006
Mixed, Deteriorating SU: undetermined MI, ER, ON: mixed, deteriorating HU: poor, deteriorating	Wetland-Dependent Bird Diversity and Abundance (4507)	2006
Mixed, Deteriorating	Coastal Wetland Area by Type (4510)	2005
Mixed, Undetermined	Effect of Water Level Fluctuations (4861)	2003
Mixed, Undetermined SU: good, unchanging MI, ER: mixed, unchanging HU: mixed, deteriorating ON: poor, unchanging	Coastal Wetland Plant Community Health (4862)	2006
Progress Report	Land Cover Adjacent to Coastal Wetlands (4863)	2006
Mixed, Undetermined	Area, Quality, and Protection of Special Lakeshore Communities—Alvars (8129)	2001
Mixed, Deteriorating	Area, Quality, and Protection of Special Lakeshore Communities—Cobble beaches (8129)	2005
Progress Report	Area, Quality, and Protection of Special Lakeshore Communities—Sand dunes (8129)	2005
Mixed, Undetermined SU: good, undetermined MI: undetermined HU, ER, ON: mixed, undetermined	Area, Quality, and Protection of Special Lakeshore Communities —Islands (8129)	2006
Mixed, Deteriorating	Extent of Hardened Shoreline (8131)	2001

Aquatic Habitat indicators

Status/Trend	Indicator Title (indicator number)	Year
Open Lake: Mixed, Undetermined Nearshore: Poor, Undetermined	Phosphorus Concentrations and Loadings (111)	2006
Mixed, Improving SU, MI, HU: fair, undetermined ER, ON: mixed, undetermined	Toxic Chemical Concentrations in Offshore Waters (118)	2006
Mixed, Improving/Undetermined	Concentrations of Contaminants in Sediment Cores (119)	2006
Undetermined	Natural Groundwater Quality and Human-Induced Changes (7100)	2005
Undetermined	Groundwater and Land: Use and Intensity (7101)	2005
Mixed, Deteriorating	Base Flow Due to Groundwater Discharge (7102)	2006
Undetermined	Groundwater Dependant Plant and Animal Communities (7103)	2005
Mixed, Deteriorating	Extent of Hardened Shoreline (8131)	2001

Other sources of aquatic habitat information

Additional information on spatial and temporal trends in toxic contaminants in offshore waters can be found in:

Marvin, C., S. Painter, D. Williams, V. Richardson, R. Rossmann, and P.Van Hoof. 2004. Spatial and temporal trends in surface water and sediment contamination in the Laurentian Great Lakes. Environmental Pollution. 129(2004): 131-144.

Kannan, K., J. Ridal, and J. Struger. 2006. Pesticides in the Great Lakes. Heidelberg Environmental Chemistry 5(N): 151-199.

Great Lakes Binational Toxics Strategy. 2002 Progress Report. Environment Canada and US EPA.

Great Lakes Binational Toxics Strategy Assessment of Level 1 Substances Summary. Great Lakes Binational Toxics Strategy (December 2005). U.S. EPA, Great Lakes National Program Office and Environment Canada.

Additional information on base flow can be found in:

Neff, B.P., Day, S.M., Piggot, A.R., Fuller, L.M. 2005. Base Flow in the Great Lakes Basin: U.S. Geological Survey Scientific Investigations Report 2005-5217, 23p.

Resource Utilization indicators

Status/trend	Indicator Title (indicator number)	Year
Undetermined	Commercial/Industrial Eco-Efficiency Measures (3514)	2003
Mixed, Undetermined SU: Mixed, Undetermined MI, HU, ER, ON: undetermined	Economic Prosperity (7043)	2003
Mixed, Unchanging	Water Withdrawals (7056)	2005
Mixed, Undetermined	Energy Consumption (7057)	2005
Undetermined	Solid Waste Disposal (7060)	2006
Poor, Deteriorating	Vehicle Use (7064)	2006
Progress Report	Wastewater Treatment and Pollution (7065)	2006

Land Use – Land Cover indicators

Status/Trend	Indicator Title (indicator number)	Year
Progress Report	Land Cover Adjacent to Coastal Wetlands (4863)	2006
Mixed, Undetermined	Urban Density (7000)	2006
Undetermined	Groundwater and Land: Use and Intensity (7101)	2005
Mixed, Undetermined	Land Cover/Land Conversion (7002)	2006
Mixed, Improving	Brownfields Redevelopment (7006)	2006
Undetermined	Sustainable Agricultural Practices (7028)	2005
Progress Report	Ground Surface Hardening (7054)	2005
Undetermined	Nutrient Management Plans (7061)	2005
Undetermined	Integrated Pest Management (7062)	2005
Mixed, Undetermined	Area, Quality and Protection of Special Lakeshore Communities – Alvars (8129)	2001
Mixed, Deteriorating	Area, Quality and Protection of Special Lakeshore Communities – Cobble Beaches (8129)	2005
Mixed, Undetermined SU: good, undetermined MI: undetermined HU, ER, ON: mixed, undetermined	Area, Quality and Protection of Special Lakeshore Communities – Islands (8129)	2006
Progress Report	Area, Quality and Protection of Special Lakeshore Communities – Sand Dunes (8129)	2005
Undetermined (Proposed Indicator)	Biodiversity Conservation Sites (8164)	2006
Mixed, Undetermined	Forest Lands – Conservation of Biological Diversity (8500)	2006
Undetermined	Forest Lands – Maintenance of Productive Capacity of Forest Ecosystems (8501)	2006
Mixed, Undetermined	Forest Lands – Conservation and Maintenance of Soil and Water Resources (8503)	2006

Human Health indicators

Status-Trend	Indicator Title (indicator number)	Year
Good, Unchanging	Drinking Water Quality (4175)	2006
Mixed, Undetermined	Biological Markers of Human Exposure to Persistent Chemicals (4177)	2006
Mixed, Unchanging SU: good, undertermined MI, ER, ON: fair, undetermined HU: good, unchanging/undetermined	Beach Advisories, Postings and Closures (4200)	2006
Mixed, Improving	Contaminants in Sport Fish (4201)	2006
Mixed, Improving	Air Quality (4202)	2006

Other sources of human health information:
Lake Wide Management Plans http://www.epa.gov/glnpo/gl2000/lamps/index.html
Agency for Toxic Substances and Disease Registry http://www.atsdr.cdc.gov/grtlakes/index.html

Climate Change indicators

Mixed, Deteriorating	Climate Change: Ice Duration on the Great Lakes (4858)	2003

Other sources of climate change information:
http://www.usgcrp.gov/usgcrp/nacc/greatlakes.htm
http://www.nrel.colostate.edu/projects/brd_global_change/proj_31_great_lakes.html
http://www.geo.msu.edu/glra/assessment/assessment.html
http://www.glerl.noaa.gov/res/Programs/ccmain.html
http://www.ucsusa.org/greatlakes/

6.0 Acronyms and Abbreviations

Agencies and Organizations

ATSDR	Agency for Toxic Substances and Disease Registry
CAMNet	Canadian Atmospheric Mercury Network
CCME	Canadian Council of Ministers of the Environment
CDC	Center for Disease Control (U.S.)
CIS	Canada Ice Service
CORA	Chippewa Ottawa Resource Authority
CWS	Canadian Wildlife Service
DFO	Canada Department of Fisheries and Oceans
EC	Environment Canada
ECO	Environmental Careers Organization
EIA	Energy Information Administration (U.S.)
GLBET	Great Lakes Basin Ecosystem Team (USFWS)
GLC	Great Lakes Commission
GLCWC	Great Lakes Coastal Wetlands Consortium
GLFC	Great Lakes Fishery Commission
GLNPO	Great Lakes National Program Office (USEPA)
IJC	International Joint Commission
IUCN	International Union for the Conservation of Nature
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
NHEERL	National Health & Environmental Effects Research Laboratory (USEPA)
NOAA	National Oceanic and Atmospheric Administration
NRC	Natural Resources Canada
NRCS	Natural Resources Conservation Service (USDA)
NYSDEC	New York State Department of Environmental Conservation
ODNR	Ohio Department of Natural Resources
ODW	Ohio Division of Wildlife
OFEC	Ontario Farm Environmental Coalition
OMAF	Ontario Ministry of Agriculture and Food
OMOE	Ontario Ministry of Environment
OMNR	Ontario Ministry of Natural Resources
OSCIA	Ontario Soil and Crop Improvement Association
ORISE	Oak Ridge Institute for Science and Education
PDEP	Pennsylvania Department of Environmental Protection
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFDA	U.S. Food and Drug Administration
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WBCSD	World Business Council for Sustainable Development
WDNR	Wisconsin Department of Natural Resources
WDO	Waste Diversion Organization (Ontario)
WiDPH	Wisconsin Department of Public Health

Units of Measure

fg	femptogram, 10^{-15} gram
ha	hectare, 10,000 square metres, 2.47 acres
kg	kilogram, 1000 grams, 2.2 pounds
km	kilometre, 0.62 miles
kt	kiloton
kWh	kilowat-hour
m	metre

mg	milligram, 10^{-3} gram
mg/kg	milligram per kilogram, part per million
mg/l	milligram per litre
ml	milliliter, 10^{-3} litre
MWh	megawatt-hour
ng	nanogram, 10^{-9} gram
ng/g	nanogram per gram, part per billion
pg	picogram, 10^{-12} gram
ppb	part per billion
ppm	part per million
ton	English ton, 2000 lb
tonne	metric tonne: 1000 kg, 2200 lb
µg	microgram, 10^{-6} gram
µg/g	microgram per gram, part per million
$\mu g/m^3$	microgram per cubic metre
µm	micrometer, micron, 10^{-6} metre

Chemicals

2,4-D	2,4-dichlorophenoxyacetic acid
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
BaP	Benzo[α]pyrene
BFR	Brominated flame retardants
CO	Carbon monoxide
DDT	1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane or dichlorodiphenyl-trichloroethane
DDD	1,1-dichloro-2,2-bis(p-chlorophenyl) ethane
DDE	1,1-dichloro-2,2-bis(chlorophenyl) ethylene or dichlorodiphenyl-dichloroethene
DOC	Dissolved organic carbon
HBCD	Hexabromocyclododecane
HCB	Hexachlorobenzene
α-HCH	Hexachlorocyclohexane
γ-HCH	Lindane
HE	Heptachlor epoxide
MeHg	Methylmercury
NAPH	Naphthalene
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NTU	Nephelometric turbidity unit
PAH	Polynuclear aromatic hydrocarbons
PBDE	Polybrominated diphenyl ether
PCA	Polychlorinated alkanes
PCB	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzo-*p*-dioxin
PCDF	Polychlorinated dibenzo furan
PCN	Polychlorinated naphthalenes
PFOA	Perfluorooctanoic acid
PFOS	Perfluoroctanyl sulfonate
PM_{10}	Atmospheric particulate matter of diameter 10 microns or smaller
$PM_{2.5}$	Atmospheric particulate matter of diameter 2.5 microns or smaller
SO_2	Sulfur dioxide
SPCB	Suite of PCB congeners that include most of PCB mass in the environment
TCDD	Tetrachlorodibenzo-*p*-dioxin
TCE	Trichloroethylene
TDS	Total dissolved solids
TOC	Total organic carbon
TRS	Total reduced sulfur
VOC	Volatile organic compound

<u>Other</u>

AAQC	Ambient Air Quality Criterion (Ontario)
AFO	Animal Feeding Operation
AOC	Area of Concern
APF	Agricultural Policy Framework (Canada)
ARET	Accelerated Reduction/Elimination of Toxics program (Canada)
BEACH	Beaches Environmental Assessment and Coastal Health (U.S. Act of 2000)
BKD	Bacterial Kidney Disease
BMP	Best Management Practices
BOB	Ballast On Board
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operations
C-CAP	Coastal Change and Analysis Program (land cover)
CC/WQR	Consumer Confidence/Water Quality Report (drinking water)
CFU	Colony Forming Units
CHT	Contaminants in Human Tissue program (part of EAGLE)
CMA	Census Metropolitan Area
CNMP	Comprehensive Nutrient Management Plan (U.S.)
CSO	Combined Sewer Overflow
CUE	Catch per Unit of Effort
CWS	Canada-wide Standard (air quality)
DWS	Drinking Water System (Canada)
EAGLE	Effects on Aboriginals of the Great Lakes program
DWSP	Drinking Water Surveillance Program (Canada)
EAPI	External Anomaly Prevalence Index
EFP	Environmental Farm Plan (Ontario)
EMS	Early Mortality Syndrome
FCO	Fish Community Objectives
FIA	Forest Inventory and Analysis (USDA Forest Service)
FQI	Floristic Quality Index
GAP	Gap Analysis Program (land cover assessment)
GIS	Geographic Information System
GLWQA	Great Lakes Water Quality Agreement
HUC	Hydrologic Unit Code
IACI	International Alvar Conservation Initiative
IADN	Integrated Atmospheric Deposition Network
IBI	Index of Biotic Integrity
IGLD	International Great Lakes Datum (water level)
IMAC	Interim Maximum Acceptable Concentration
IPM	Integrated Pest Management
ISA	Impervious Surface Area
LaMP	Lakewide Management Plan
LEL	Lowest Effect Level
MAC	Maximum Acceptable Concentration
MACT	Maximum Available Control Technology
MCL	Maximum Contaminant Level
MGD	Million Gallons per Day (3785.4 m^3 per day)
MMP	Marsh Monitoring Program
MSA	Metropolitan Statistical Area
MSWG	Municipal Solid Waste Generation
NAFTA	North America Free Trade Agreement
NATTS	National Air Toxics Trend Site (U.S. network)
NEI	National Emissions Inventory (U.S.)
NHANES	National Health and Nutrition Examination Survey (CDC)
NIS	Nonindigenous species

NLCD	National Land Cover Data
NMP	Nutrient Management Plan (Ontario)
NOAEC	No Observable Adverse Effect Concentrations
NOAEL	No Observable Adverse Effect Level
NOBOB	No Ballast On Board
NPDES	National Pollution Discharge Elimination System (U.S.)
NPRI	National Pollutant Release Inventory (Canada)
NRVIS	Natural Resources and Values Information System (OMNR)
ODWQS	Ontario Drinking Water Quality Standard
OPEP	Ontario Pesticides Education Program
PEL	Probable Effect Level
PBT	Persistent Bioaccumulative Toxic (chemical)
PNP	Permit Nutrient Plans (U.S.)
PGMN	Provincial Groundwater-Monitoring Network (Ontario)
RAP	Remedial Action Plan
SDWIS	Safe Drinking Water Information System (U.S.)
SOLEC	State of the Lakes Ecosystem Conference
SOLRIS	Southern Ontario Land Resource Information System
SQI	Sediment Quality Index
SSO	Sanitary Sewer Overflow
SWMRS	Seasonal Water Monitoring and Reporting System (Canada)
TCR	Total Coliform Rule
TDI	Tolerable Daily Intake
TEQ	Toxic Equivalent
TIGER	Topological Integrated Geographic Encoding and Reference (U.S. Census Bureau)
TRI	Toxics Release Inventory (U.S.)
UNECE	United Nations Economic Commission for Europe
WIC	Women Infant and Child (Wisconsin health clinics)
WISCLAND	Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data
WTP	Water Treatment Plant (U.S.)

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U.S. Geological Survey
- Biological Resources Division
- Great Lakes Science Center
  - Lake Erie Biological Station
  - Lake Ontario Biological Station
  - Lake Superior Biological Station
- Water Resources Discipline

Provincial and State
Illinois Department of Natural Resources
Illinois Environmental Protection Agency
Indiana Department of Natural Resources
Indiana Geological Survey
Michigan Department of Environmental Quality
Michigan Department of Natural Resources
Minnesota Department of Health
Minnesota Department of Natural Resources
Minnesota Pollution Control Agency
New York State Department of Environmental Conservation
Ohio Department of Natural Resources
Ohio Division of Wildlife
Ontario Ministry of Agriculture and Food
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Coalitions
Binational Collaborative for the Conservation of Great Lakes Islands
Great Lakes Coastal Wetlands Consortium
Great Lakes Environmental Indicators

Commissions
Great Lakes Commission
Great Lakes Fishery Commission
Great Lakes Indian Fish and Wildlife Commission
International Joint Commission

Environmental Non-Government Organizations

Bird Studies Canada
Great Lakes Forest Alliance
Great Lakes United
The Nature Conservancy

Industry
American Forests and Paper Association
Council of Great Lakes Industries
National Council for Air and Stream Improvement, Inc.

Private Organizations
Bio-Software Environmental Data
Bobolink Enterprises
DynCorp, A CSC Company
Environmental Careers Organization
LURA Consulting
Oak Ridge Institute for Science and Education
Stream Benders

Private Citizens