Great Lakes Trends: Into the New Millennium

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Prepared by
Office of the Great Lakes
Michigan Department of Environmental Quality

This report updates and expands the *Great Lakes Trends: A Dynamic Ecosystem* prepared by the Office of the Great Lakes, Michigan Department of Environmental Quality, in 1998.

Special thanks to Emily Bankard, Intern in the Office of the Great Lakes and, Jim Bredin, who, as in 1998, served as editor.

This report was derived from many sources, too numerous to mention. The major sources are identified in the References section of this report. We would like to thank all contributors for the information provided.

Periodically, the Michigan Office of the Great Lakes prepares trends analyses to update the public on current Great Lakes trends. If you have suggestions for future trends reports, your comments are welcome and should be sent to:

Michigan Office of the Great Lakes
Department of Environmental Quality
P.O. Box 30473
Lansing, Michigan 48909-7973
Phone: 517-335-4232 or 517-335-4056
Fax: 517-335-4053
E-mail: bredinj@state.mi.us

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PURPOSE OF THE REPORT

This report is a continuing effort by the Office of the Great Lakes to provide information regarding trends of importance to the Great Lakes ecosystem. It provides more recent and extensive trends information, building on Great Lakes Trends: A Dynamic Ecosystem published in 1998. This report documents changes in chemical, physical and biological components of the ecosystem. The Office of the Great Lakes prepared this follow-up report to provide clearer definition of the current state of the Great Lakes, and at the same time, provide insight into the future management issues of consequence to the lakes.

This report is organized according to the three major components of the Great Lakes Basin ecosystem: chemical, physical and biological. The report also includes a summary of Great Lakes trends at the conclusion.

INTRODUCTION

Pursuant to Act 128 of the Public Acts of 1985, the Office of the Great Lakes, within the Michigan Department of Environmental Quality, prepares an annual report on the state of the Great Lakes. Two earlier editions, 1993 and 1995, contain entries addressing past and present environmental trends of the Great Lakes. In 1998, as supplement to those annual reports, the Office of the Great Lakes prepared the Great Lakes Trends: A Dynamic Ecosystem. This new report expands upon the previous reports. These documents demonstrate how far protection of the Great Lakes has come, but they also remind us how much remains to be done.

In 1972 the United States and Canada signed the Great Lakes Water Quality Agreement. They amended the agreement in 1978 and 1987. The agreement aimed "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." It bound the parties to "make a maximum effort to develop programs, practices and technology necessary for a better understanding of the Great Lakes Basin Ecosystem, and to eliminate or reduce to the maximum extent practicable the discharge of pollutants into the Great Lakes Ecosystem." The agreement defines the Great Lakes Ecosystem as "the interacting components of air, land, water and living organisms, including humans, within the drainage basin of the St. Lawrence River at or upstream from the point at which this river becomes the international boundary between Canada and the United States." The agreement represents a broad commitment to Great Lakes Basin health.

CHEMICAL TRENDS

There are a number of significant programs currently underway in the Great Lakes Basin that are of critical importance to continued environmental improvement through the reduction of chemical contaminants. There are two programs, recently initiated, that are of importance to future reduction of Great Lakes contaminants: the Great Waters Program and the Great Lakes Binational Toxics Strategy.

The Great Waters Program of the Clean Air Act Amendments of 1990 requires the establishment of air monitoring networks to collect data to help identify and track movement of air pollutants into Great Lakes ecosystems and determine overall pollution loadings from the air. The adjacent table lists pollutants identified in the Great Waters Report. This program also is used to evaluate the effectiveness of existing regulatory programs in addressing these problems and to determine whether additional regulatory actions are needed to reduce atmospheric deposition to the Great Lakes. Efforts under the Great Waters Program include:

Pollutants Identified in the Great Waters Report to Congress
Chlordane
DDT/DDE
Dieldrin
Hexachlorobenzene
a-Hexachlorocyclohexane
Lindane
Lead & Lead Compounds
Mercury & Mercury Compounds
PCBs
Polycyclic Organic Matter
TCDD/TCDF
Toxaphene
Cadmium & Cadmium Compounds
Nitrogen Compounds

- monitor hazardous pollutants by establishing sampling networks,
- investigate the deposition of these pollutants,
- improve monitoring methods for these hazardous pollutants in fish and wildlife to determine the contribution of air pollution to total pollution,
- evaluate any adverse effects to public health and the environment, and
- determine sources of pollution.

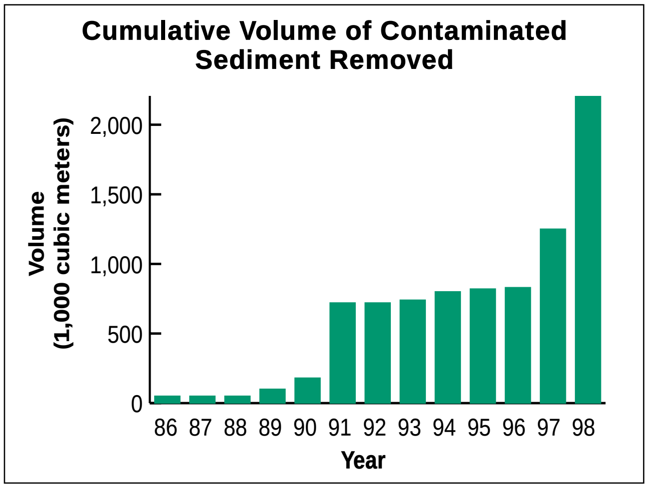
The Canada-United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes Basin, known as the Great Lakes Binational Toxics Strategy, is an on-going, bi-national, public and private effort to address persistent toxic substances in the Great Lakes Basin. This Strategy focuses on use and emission reduction. The Great Lakes Binational Strategy provides a framework for actions to reduce or eliminate persistent toxic substances, especially those which bioaccumulate, from the Great Lakes Basin. A list of these substances can be found in the adjacent table.

Great Lakes Binational Toxics Strategy
Substances to be Virtually Eliminated
Aldrin/Dieldrin
Benzo (a) pyrene
Chlordane
DDT (and DDD,DDE)
Hexachlorobenzene
Alkyl-lead
Mercury and mercury compounds
Mirex
Octachlorostyrene
PCBs
PCDD (Dioxins) and PCDF (Furans)
Toxaphene

The Strategy establishes reduction challenges for persistent toxic substances targeted for virtual elimination. These substances have been associated with long-term adverse effects on wildlife in the Great Lakes through bioaccumulation and are of concern for human health. Recognizing the long-term nature of virtual elimination, the Strategy provides the framework for actions to achieve quantifiable "challenges" in the timeframe 1997 to 2006 for specific toxic substances. The U.S. Environmental Protection Agency and Environment Canada have involved state, provincial, tribal, industrial, environmental and other interested parties, recognizing that the governments alone cannot achieve the goal of virtual elimination — all parts of society must cooperate to ensure success.

Water Quality

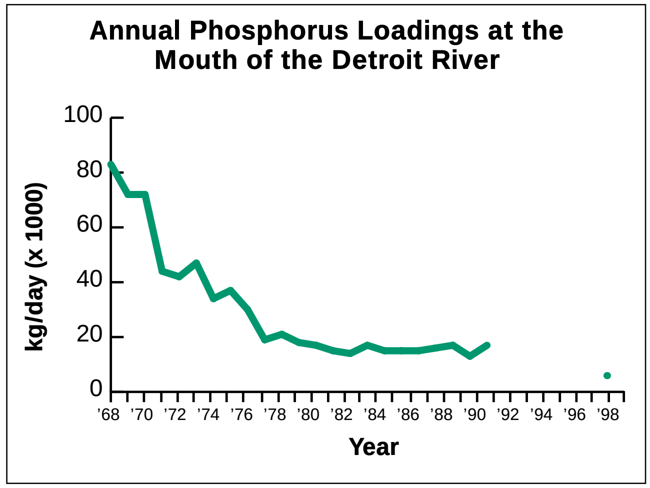
Great Lakes water quality trend data are available from fixed station monitoring at the mouth of the Detroit River and at 16 major tributaries of the Great Lakes. The parameters examined to determine changes and trends over time include phosphorus, suspended solids, chloride, lead, copper and zinc. Concentrations and loading rates of suspended solids, chlorine, lead, copper, and zinc have decreased. Point source controls implemented in the Detroit River and many other Great Lakes tributaries having industrial and municipal discharges resulted in substantial water quality improvements for a variety of parameters. Some tributaries without point source pollution source discharges did not reflect these reductions. Annual mean concentrations and loading rates for all parameters except suspended solids have decreased at the downstream Detroit River transect since monitoring began in the 1960s.



Source: International Joint Commission, 1999.

Removal of contaminated sediments from the Great Lakes and tributaries has increased in the past ten years as shown in the adjacent figure. All 42 Areas of Concern, areas of the Great Lakes identified as having significant impairment of uses, have contaminated sediment based on the application of chemical guidelines; but the effects of those contaminants on the ecosystem is only partially quantified[1]. However, there are clear linkages to restrictions on fish and wildlife consumption, fish tumors or other deformities, loss of fish and wildlife habitat, degraded natural communities, and other ecosystem effects. Progress in removing the contaminated sediment from the Great Lakes ecosystem has accelerated in recent years. Unfortunately, few projects have information on ecological effectiveness gained through post-project monitoring of the recovery of beneficial uses.

The adjacent figure illustrates the phosphorus concentration and loading rate reductions in the Detroit River. Most of the Great Lakes tributaries monitored over the past 16 years have shown similar trends and have resulted in improved water quality and a slowing of the eutrophication (increasing nutrient levels) of the Great Lakes[1,2]. Point source discharge controls have been responsible for most of the reduction.



Source: Michigan Department of Natural Resources, 1984 and U.S. Geological Survey, 1999 (data unavailable for 1991-97).

In the past 20 years, Lake Erie has shown the greatest improvement of the Great Lakes in levels of conventional contaminants such as phosphorus and nitrogen. Annual average concentrations of conventional contaminants have been reduced by approximately 50 percent over the last 15 years. The principal reason for this improvement was control of point source discharges to the Detroit River.

In all Great Lakes, significant loadings of phosphorus have been reduced due to reductions in the amount of phosphorus allowed in household laundry detergents. Province of Ontario's strict regulatory controls have also reduced phosphorus loadings. In Lake Michigan, Lake Superior and the Detroit River phosphorus and chlorophyll concentrations in open waters have decreased significantly since the late 1970s. The amount of phosphorus entering Lake Erie has decreased by approximately 10,000 metric tons a year since 1972. Even with this significant decrease the phosphorus levels in Lake Erie have been increasing in the central and eastern basins. Recent data available through the Lake Michigan Mass Balance indicate that concentrations may also be increasing in Lake Michigan

Trophic status, as shown for Michigan inland lakes in the adjacent table, is a measure of the fertility or nutrient level of a lake. It combines several parameters related to plant nutrients such as nitrogen and phosphorus content of the water column. Plant and algae growth in the Great Lakes and most inland lakes of eastern North

Trophic Status of Michigan Inland Lakes (Nutrient Level)	Number of Lakes	Acres
Oligotrophic (low)	115 (16%)	172,591 (35%)
Mesotrophic (moderate)	375 (51%)	175,307 (36%)
Eutrophic (high)	207 (28%)	124,881 (25%)
Hypereutrophic (excessive)	33 (5%)	19,152 (4%)

Source: Department of Environmental Quality, 1998.

America are usually phosphorus limited. As the amount of phosphorus in the water column increases, aquatic vegetation and algae growth increases. When extra nutrients such as phosphorus are added to the water column, the eutrophication process is accelerated. Most inland lakes have moderate nutrient levels.

Deeper, colder lakes, with less plant and algal growth, are termed oligotrophic. They become more eutrophic with age as the amount of growth increases. The adjacent table identifies the trophic status of the Great Lakes.

Trophic Status of the Great Lakes

Lake	***Trophic Status (nutrient level)***
Superior	Oligotrophic (low)
Huron	Oligotrophic (low)
Saginaw Bay	Eutrophic (high)
Michigan	Oligo/mesotrophic (moderate)
Erie	Mesotrophic (moderate)
Western Basin	Eutrophic (high)
Ontario	Mesotrophic (moderate)

Source: Department of Environmental Quality, 1996.

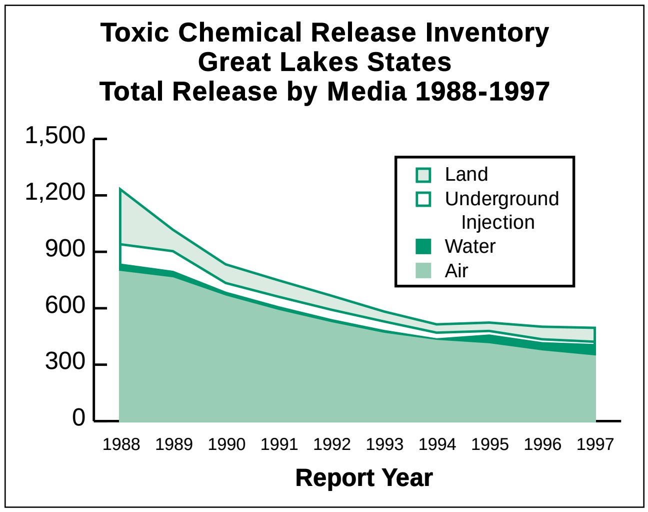
Another issue facing the Great Lakes is increased chloride levels. Chlorides are used as an indicator of urban runoff. Above average levels of salt, or sodium chloride, in Michigan rivers serve as indicators of human activities. Increases in chlorides result in increases in conductivity or dissolved content of salt ions in the water. As these levels increase above natural levels, aquatic organisms must adapt to higher levels or move to another body of water. Lake Michigan's chloride concentration is increasing at a slow rate[3]. However, the rate of increase of chloride concentrations continues to climb. The primary source of chloride is believed to be municipal wastewater discharges and from use of salt in road deicing. Lakes Ontario and Erie have decreased chloride inputs as a result of effective programs to control potential sources of additional chloride[3].

Lakes Superior, Michigan and Huron have excellent water quality[2]. However, historical data suggest that Lake Superior has been measurably changed by localized input of excessive nutrients and by localized toxic contaminant problems. Lake Huron also exhibits high water quality due to control of point source discharges from the Saginaw River since the 1970s which has resulted in substantial declines in pollutants. All Michigan waters of the Great Lakes fully support secondary contact recreation (non-swimming), agriculture, industrial and navigation uses. Due to fish consumption advisories, 3,250 miles of the Great Lakes do not fully support designated uses. Ninety-nine percent of beaches support swimming and 97.5 percent support drinking water use. Within Michigan, portions of rivers and lakes are not supporting designated uses. Current monitoring programs indicate that the Water Quality Standards are not being met in roughly 1,704 river miles of a total assessed 20,575 miles and 54,039 acres of inland lakes of a total of 491,931 acres assessed. About 10 percent of river miles and inland lake acres are not supporting designated uses[2].

Some swimming beaches on Lake Huron, Lake Michigan, Lake St. Clair, St. Marys River and other areas of the Great Lakes were periodically closed by the local health departments due to excessive bacterial (E. coli) counts[4]. Beach closures are due to the elevated density of pathogenic organisms. In many areas sources of the elevated bacterial densities and potential pathogens appears to be urban stormwater runoff and combined sewer overflows from urban areas to streams along the shoreline. Major efforts are underway to update surface water discharge permits in an attempt to minimize or eliminate future water quality violations.

The concentrations of metals, such as mercury and lead, in most of the Great Lakes are on a downward trend as compared to levels found 20 years ago. Lead and mercury concentrations for Lake Michigan in dated sediment cores indicate peaks in the 1920 to 1970 time period with decreases starting in the middle 1970s. Similar trends can be seen in other Great Lakes.

From report years 1988 through 1997, releases of hazardous chemicals by the eight Great Lakes states, tracked through the Toxic Release Inventory, have declined significantly as shown in the adjacent figure. The Inventory requires manufacturing facilities meeting certain activity thresholds to report their estimated releases, transfers and storages of the listed toxic chemicals. This figure does not take into account that chemicals over the years have been removed from or added to the list of reportable chemicals.



Source: U. S. Environmental Protection Agency, Envirofacts Data Warehouse.

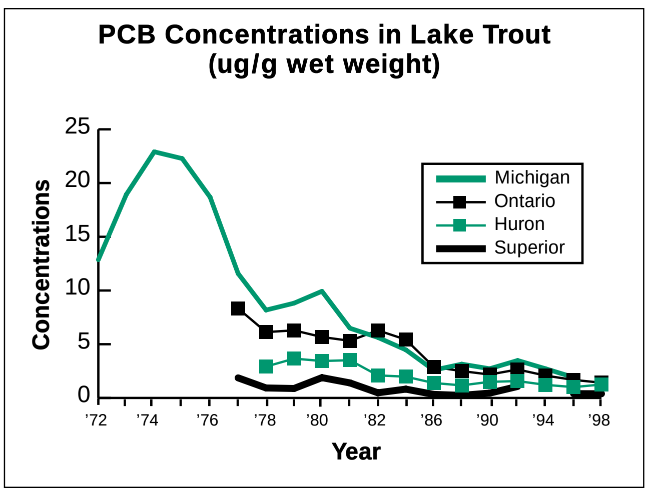
Based on the Toxic Release Inventory, toxic chemical releases from Michigan industries continue to decline, falling by nearly 10 percent during the three most recent reporting years. Michigan facilities reported total releases of 82.0 million pounds of toxic chemicals in 1998, a 10.0 percent reduction from the 1997 reporting year. Specifically, Michigan air emissions have declined from 45 million pounds in 1997 to 40 million pounds in 1998. In fact, discharges to surface waters of the state fell from 717,000 pounds to 480,000 pounds. Also releases from underground injection wells dropped from 2.3 to 2.1 million pounds.

The federal Pollution Prevention Act of 1990 required facilities to also report waste management and pollution prevention activities for the listed toxic chemicals. Facilities began reporting on-site and off-site management of waste materials as well as source reduction activities implemented in a given report year.

The decreases identified in the above Toxic Chemical Release Inventory figure cannot be attributed to any one factor. In Michigan, over the course of years, reported releases may have decreased because facilities have switched to alternative materials in place of toxic chemicals. Or they may have changed their production processes, improved their measurement and calculations, or managed their waste materials through recycling, energy recovery or treatment rather than release or disposal. The reporting of Toxic Release Inventory data to the public under the community right-to-know provision of federal law also could be a reason for the decreases seen. The Toxic Release Inventory data does contribute to the public perception of a facility's environmental health, and may influence a facility's effort to reduce or eliminate its use of toxic chemicals. New industry sector's data are reporting for the first time in 1998, and an overall increase in the reported releases is expected.

Persistent, Bioaccumulative Toxics

The Great Lakes watershed continues to have problems with persistent, bioaccumulative toxics such as polychlorinated byphenyls (PCBs), chlordane, mercury, and dioxins. Based on the amount of PCB uptake by fish, Water Quality Standards are not being met for PCBs in Michigan waters of the Great Lakes. The long-term trends for PCB concentrations are decreasing in some species such as lake trout (see adjacent figure). Since the 1970s, when many persistent, bioaccumulative toxics such as PCB and DDT were banned, levels of these parameters in Great Lakes fish tissues have declined.



Source: Devault, 1989 and U.S. Environmental Protection Agency, 1999.

Changes in fish tissue concentrations can be variable and dependent on the period of record, fish species and lake. In addition, some contaminant trends (e.g. PCBs and DDT in Lake Huron lake trout) are characterized by short-term decreases with the long- term trend being downward. Some investigators hypothesize that recent changes in contaminant concentrations may be more related to changes in the food chain or lipid content of lake trout and their prey. Currently, contamination from these persistent bioaccumulative toxics are most likely being influenced by biological factors within each lake system.

PCB levels in herring gulls and in the water column has declined significantly since 1980. In the mid-90s this trend began to level out and in Lake Michigan the levels showed a slight increase in concentrations in coho salmon. PCB levels in lake trout have not shown a steady downward trend since 1986, but have begun to level off and stabilize. Nevertheless, contaminant levels are not simply a reflection of the environmental concentrations. Other factors such as fish lipid content, position in the food chain and trophic structure of the wildlife also determine the distribution of persistent organic contaminants in the environment. Changes in concentrations may be due to changing growth dynamics caused by exotic species' induced changes in the food chain as opposed to new sources of contaminants to the Great Lakes.

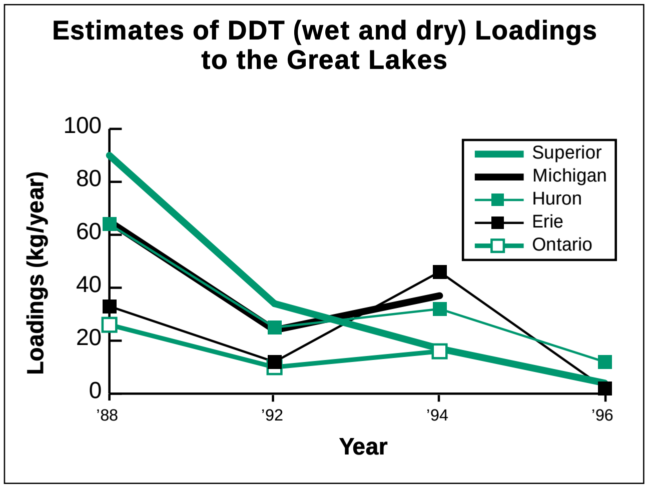
Pesticides have been a significant problem in the Great Lakes for a number of years. Pesticides such as chlordane, dieldrin, and DDT had impacted wildlife and resulted in sustained action by the Great Lakes federal, provincial and state agencies.

- ***Chlordane*** is an organochlorine insecticide that was used for domestic control of termites and carpenter ants and for control of agricultural soil pests such as corn rootworm and strawberry root weevil. The high persistence and high lipid solubility of chlordane results in concern about its bioaccumulation in the aquatic food chain. Agricultural uses were restricted in the late 1970s. In Canada, federal registration was discontinued in 1990 and Ontario banned its use in 1994. The United States restricted its use in 1981 to termite control and registrants voluntarily removed chlordane from the market. Chlordane is not a single chemical, but is a mixture of more than 50 chemicals. Because it does not dissolve in water before it can be used, it must be placed in water with emulsifiers (soap-like substances) to make a milky-looking mixture of liquid particles.

  Use of chlordane was stopped, mainly, because of concern over cancer risk, evidence of human exposure, build up in body fat, persistence in the environment, and danger to wildlife. This compound stays in the environment for many years and is still found in food, air, water, and soil, and is also present in some form in the fat of almost all humans

- ***Dieldrin*** is an organochlorine pesticide previously registered for corn pests, termite control, and moth control on clothing and carpets. Estimates of loadings into the Great Lakes have declined since it was banned in the United States in 1974, except for termite control. In Ontario, its use was banned in 1994. Dieldrin is also a metabolic conversion product of aldrin, another pesticide, and can be expected to appear in the environment following the use of either chemical. Dieldrin was first introduced in the 1950s for use by cotton growers when the chemical was found to be more effective than aldrin, and later, was used as an insecticide for other crops, for public health pest control, and for mothproofing woolen goods. Not only are these compounds hazardous to wildlife, but laboratory testing indicates a strong likelihood that these substances, which regularly contaminate human foods, can cause cancer in humans.

- ***DDT***, an organochloride pesticide, was widely used following World War II and devastated many bird populations by causing the birds to lay thin-shelled eggs that broke during incubation. The insecticide was introduced into North America in 1946. DDT was banned from use in the United States in 1972 and banned in Ontario in 1989. DDT levels have decreased significantly in the Great Lakes as shown by the adjacent figure[5].



Source: U.S. Environmental Protection

- ***Toxaphene*** is a nonselective pesticide that was introduced in the late 1940s. This pesticide was mainly used in the south prior to its cancellation in 1982. In 1972 application of this hazardous pesticide was widely accepted because all of the attention was on DDT. The U.S. Environmental Protection Agency had just banned DDT. When compared to DDT, toxaphene appeared to be a better alternative. By 1990 the U.S. Environmental Protection Agency had banned all uses of toxaphene within the United States; however, several countries continue to use the pesticide.

  Due to the apparent lack of decline of toxaphene concentrations in fish from Lake Superior and northern Lake Michigan, some researchers argue that declines in toxaphene should be occurring at the same rate as declines in concentrations of other banned pesticides. In a study of sediment cores, two cores from northern Lake Michigan had higher surface concentrations. The other cores were similar to the surface of one of the control lakes. The similar concentrations among all Great Lakes cores and the control lake core provide strong evidence that the dominant source of toxaphene to the Great Lakes is atmospheric deposition.

Action by governmental agencies resulted in significantly decreased pesticide concentrations in the Great Lakes. Great Lakes issues and associated success stories regarding potential pesticide impacts include[6]:

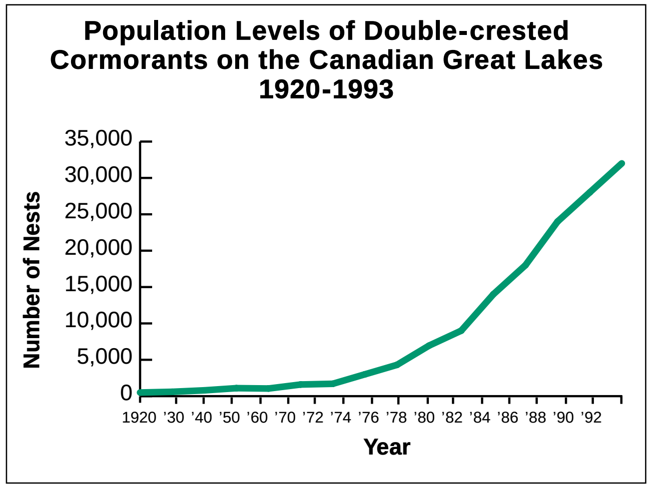
- In 1963, fewer than 500 pairs of bald eagles were found in the lower 48 states. Since that time their numbers have increased ten-fold, according to the U.S. Fish and Wildlife Service. In 1996, more than 5,000 pairs were counted. In August 1995, the eagle was downlisted from endangered to threatened status under the Endangered Species Act.

- In 1975, only 39 breeding pairs of peregrine falcons were counted in the entire lower 48 states, and all of them were in the west. The peregrine population in the eastern United States had been completely eradicated by DDT poisoning. In

1996, 993 pairs were counted in the lower 48 states, a more than twenty-fold increase. This included 153 pairs re-established in the eastern United States. Falcons have made their homes in a number of Great Lakes cities.

- Ospreys have increased from fewer than 8,000 breeding pairs nationwide in 1981 to 14,246 pairs in 1994.

The preeminent sentinels of the Great Lakes are fish eating birds. With Great Lakes fish being good indicators of environmental conditions, fish-eating birds provide a means of analyzing the potential impacts of contaminants on the Great Lakes ecosystem. Double-crested cormorants, common terns, Forster's terns, caspian terns, herring gulls, osprey and bald eagles have been the birds most frequently studied.



Source: Environment Canada, 1999.

Compared to 1970s populations, the number of fish-eating birds had significantly increased by the late 1980s[7]. As shown in the adjacent figure, cormorant populations are higher now than any time in the last century. Since release of the previous Great Lakes Trends Report, additional cormorant monitoring has occurred and the number of nests in the Great Lakes are still increasing significantly. Herring gull numbers have increased and the reproductive success of Forster's terns has also increased[8].

The table below identifies recent trends in organochlorine contaminants in Herring Gull eggs from colonies on the Great Lakes between 1990 and 1995. As shown in the table, most lakes for most contaminants show no significant changes over the five-year time period. Dieldrin, oxy-chlorane, a-HCH and 1,2,3,4-TCB show decreased levels in some locations.

Lake		Ontario	Erie	Huron		Michigan	Superior
Contaminant	**Description**	Mugg's Island	Middle Island	Channel-Shelter Island	Double Island	Big Sister Island	Granite Island
DDE	Breakdown component of DDT	**No Significant Changes**					
PCBs	Industrial Use	**No Significant Changes**					
Dieldrin	Insecticide	↓	—	—	—	—	—
HCB	Fungicide & Industrial Bi-product	**No Significant Changes**					
Mirex	Insecticide	**No Significant Changes**					
Oxy-chlorane	Insecticide	↓	—	—	—	—	—
a-HCH	Component of Lindane – Insecticide	—	—	—	↓	—	↓
1,2,3,4-TCB	Industrial Bi-product	—	—	—	↓	—	—

(- Levels have remained the same, (Levels have decreased significantly)
HCB: Hexachlorobenzine, a-HCH: alpha-hexachlorocyclohexane, 12,3,4-TCB: 1,2,3,4 tetrachlorobenzene
Source; D.P. Ryckman, et al. 1997.

A comparison of organochlorines in eggs of Great Lakes fish-eating birds collected between 1971 and 1989 indicate a pattern of decreasing concentrations shown in the above table. Most data show that concentrations of PCBs, DDE, Mirex, HCB and dioxins decreased significantly until the early 1980s. Concentrations after the early 1980s have remained relatively constant.

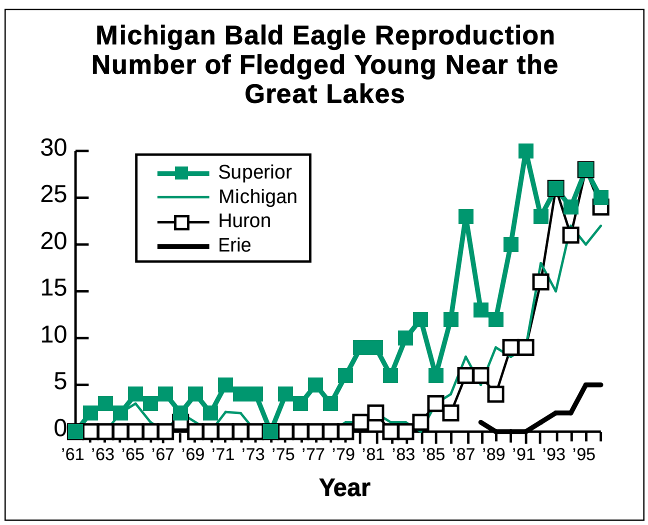
Many Great Lakes scientists are concerned about the potential that some man-made chemicals may be interfering with normal endocrine system functioning in both humans and wildlife. There seems to be greater scientific consensus that endocrine disruptors may be causing an impact on wildlife systems. Considerable scientific uncertainty remains, however, as to which chemicals may be involved, patterns of exposure, mechanisms of action in humans and wildlife, and the best means for testing to predict or screen for these effects.

Hormones are chemicals that travel through the bloodstream and cause responses in other parts of the body. Examples of hormones include adrenaline and estrogen. Hormones can produce both positive and negative effects. Chemicals that interfere with the normal functioning of this complex system are known as “endocrine disruptors.” Some chemicals may mimic a natural hormone, “fooling” the body into overresponding to the hormone. Other chemicals may block the effects of a hormone in parts of the body normally sensitive to it while others may directly stimulate or inhibit the endocrine system, leading to overproduction or underproduction of hormones.

Federal and state agencies have already banned the use in the United States of a number of the more environmentally persistent chemicals that have raised concerns about possible hormonal effects (PCBs, and such organochlorine pesticides as DDT, chlordane, aldrin/dieldrin, endrin, heptachlor, kepone, toxaphene, and 2,4,5-T). In many instances these bans were initiated because of effects on wildlife. These agencies are working with the international community to limit production and use of these chemicals worldwide. The U.S. Environmental Protection Agency is planning a reassessment of four organochlorine pesticides (dicofol, methoxychlor, lindane, and endosulfan) that remain on the United States market, with the goal of identifying any potential combined or cumulative effects. The U.S. Environmental Protection Agency is also revising its testing guidelines for evaluating the effects of pesticides and toxic substances on reproduction and the developing fetus. State and federal agencies continue to encourage actions to reduce unnecessary chemical exposure and promote pollution prevention efforts. Current studies have not shown a link from exposures of hormone disruptors to human reproduction and development; however, further research is needed to determine if there is a relationship between specific hormones and biological effects[9].

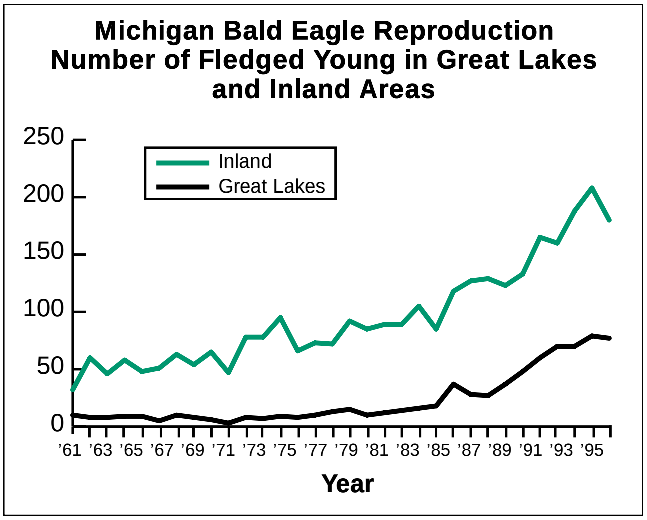
Case of the Bald Eagle[10]

Since initiation of large-scale monitoring programs in the 1970s, there has been a general decline in contaminant concentrations in Great Lakes biota such as fish and the eggs of fish eating birds. An example of this has been the bald eagle, which is high on the food chain and accumulates high concentrations of toxic chemicals. The bald eagle population in the state of Michigan has continued to grow from 1961 to 1996. Reproductive productivity has increased over time and is near 1.0 young per occupied nest recently. However, during this period productivity varied among breeding areas in Michigan, with interior breeding areas having significantly greater productivity than Great Lakes breeding areas (areas on the Great Lakes and also areas not directly on the Great Lakes but are accessible to runs of Great Lakes fish).



Source: Bowerman, William W. 1997.

Interior bald eagle breeding areas have typically maintained a reproductive productivity rate at 1.0 young per occupied nest since 1975. Great Lakes breeding areas have steadily increased to near 0.9 young per occupied nest since 1961. Lake Superior shorelines sustain the largest numbers of fledged young shown in the adjacent figure. The current productivity within the Great Lakes subpopulations during the period of 1985 to 1996 are considered just sufficient to maintain a population, and insufficient to permit an increase.



Source: Bowerman, William W. 1997.

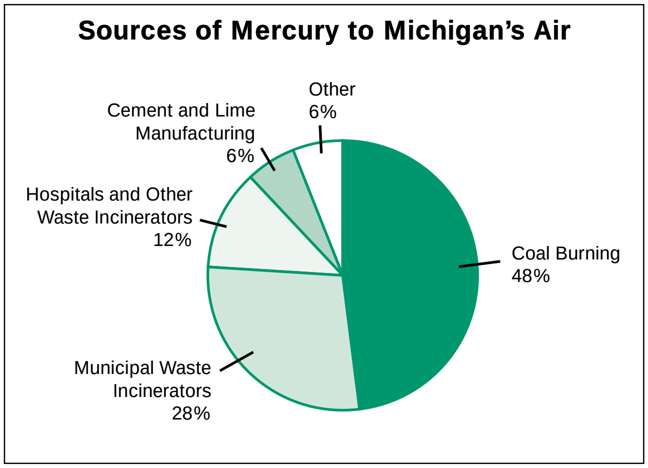
While the number of breeding pairs along the Great Lakes has increased from 1961 to 1996, the growth is attributed to the relative greater productivity of the interior Michigan, Wisconsin and Minnesota nesting birds. These birds have provided not only enough young to produce an increase in the interior areas but to repopulate historic and other available habitat along the Great Lakes shoreline. The number of fledged young on inland lakeshores is higher than the Great Lakes as shown on the adjacent figure.

Bald eagle nesting along the Great Lakes shorelines and interior areas accessible to runs of Great Lakes fish contain greater concentrations of chlorinated hydrocarbons such as pesticides and PCBs in blood plasma and addled eggs, than those eagles from more interior sites. There are, however, subpopulations that have greater adult mortality and impaired reproductive productivity[10].

Contaminant concentrations in eggs of bald eagles nesting in the region are experiencing a downward trend. In the past the population declined due to reproductive failure resulting from breakage of thin-shelled eggs. Studies throughout North America have found that if eggs contain less than 3 parts per million (ppm) of DDE and 4.5 ppm of PCBs, then about the normal number of young are produced. While concentration trends in eggs are downward, they are not yet at levels where normal reproduction would be expected.

Mercury: A Multi-Media Issue[11]

Mercury, a heavy metal, persists in the environment and bioaccumulates. Mercury surpasses PCBs as a cause of fish consumption advisories in inland lakes but not in the Great Lakes or inland rivers. Forty states have issued mercury-related health advisories due to fish consumption with 10 states issuing statewide advisories. Michigan issued a statewide advisory for all 11,000 of the state's inland lakes in 1989. From 1983 to 1994, use of mercury in the United States has, according to the U.S. Environmental Protection Agency, decreased by 72 percent. However, mercury remains a problem in the environment due to on-going air emissions and deposition to water.

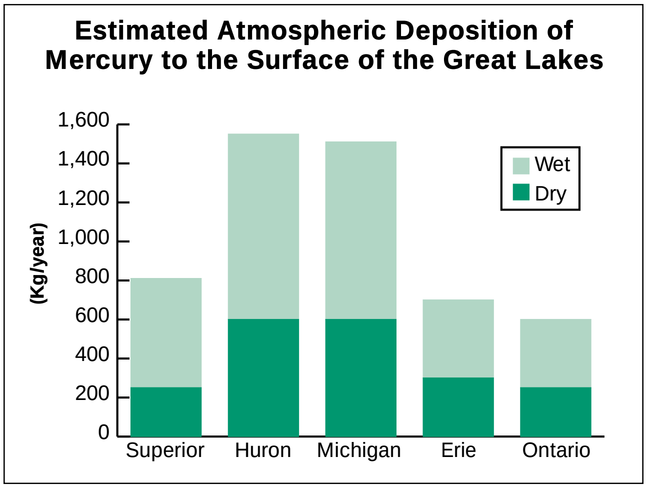


Source: Michigan Mercury Pollution Prevention Task Force, 1996.

According to the U.S. Geological Survey, best estimates are that human activities have doubled or tripled the amount of mercury in the atmosphere. The atmosphere burden has increased by roughly 1.5 percent per year. Major sources of mercury to the atmosphere are coal combustion, chlorine alkali processing, waste incineration and metal processing shown in the adjacent figure.

Mercury is a potent neurotoxin, particularly in the organic, methyl-mercury form, capable of impairing neurological development in fetuses and young children and damaging the central nervous system of adults. People are most likely to be exposed to harmful quantities of mercury through consumption of fish contaminated with methylmercury.

Most environmental releases of mercury are inorganic, either in the elemental or ionic form. Most emissions of ionic mercury deposit within the region of the source, while elemental mercury enters a global atmospheric reservoir where it can remain for approximately one year, potentially traveling long distances. In the environment, these forms of mercury can be converted to methylmercury, which can bioaccumulate reaching dangerous levels in fish at the top of the aquatic food chain. Mercury does not degrade and is not destroyed by combustion.



Source: Michigan Environmental Sciences Board, 1993.

Mercury cycles extensively between soils, the atmosphere, and surface waters. Scientists believe that atmospheric deposition of mercury emitted into the air by combustion, incineration, or manufacturing processes, contributes a large portion of the mercury found in waters and soils. The largest amounts of deposition occur in Lake Huron and Lake Michigan, illustrated in the adjacent figure. In Minnesota, researchers estimated that in 1995, direct industrial discharges of mercury to surface water contributed only 1 to 2 percent of the mercury load to surface waters, while atmospheric deposition was responsible for 98 percent.

The table below identifies the decreasing industrial demand for mercury and the increasing secondary production. Secondary production is the recovery of mercury from discarded products and industrial wastes such as chlor-alkali wastes, dental amalgams, fluorescent light tubes, electronic devices, batteries, and other instruments such as thermometers. Secondary production of mercury now produces enough mercury to meet the demands of industry, reducing the reliance on mercury mining.

Secondary Mercury Production in the United States (Tons)

	1950	1960	1970	1980	1990	1995	1997
Industrial Demand (Consumption)	1,867	1,940	2,332	2,236	792	480	381
Secondary Production (Industrial)	76	202	278	257	119	587	428
Percentage	4%	10%	12%	12%	15%	122%	112%

Source: United States Environmental Protection Agency and Environment Canada, 1999/U.S. Geological Survey Mineral Yearbook, 1997.

In 1993, Michigan developed a Mercury Action Plan in an effort to respond to recommendations made in the Michigan Environmental Science Board report, "Mercury in Michigan's Environment: Environmental and Human Health Concerns." This action plan was the impetus behind the formation of the Michigan Mercury Pollution Prevention Task Force that led to many state and regional partnerships and projects that focus on mercury reduction and pollution prevention.

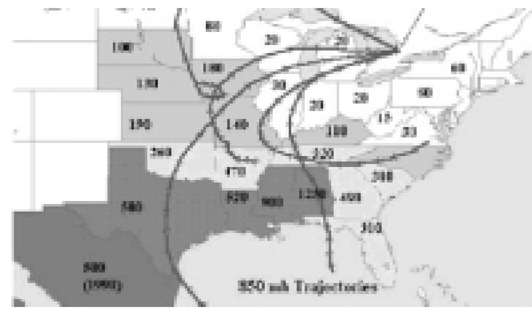
Atmospheric Sources of Pollutants

Waterbodies can be impacted by pollution sources that are far removed from the area. Long-range atmospheric transport and deposition of pesticides has been documented by numerous researchers, and is now believed to contribute significantly to contaminant inputs to the Great Lakes. Traces of pesticides and other chemicals have been found in the uninhabited polar-regions of the North.

> ***"Because contamination from industrial sources has been largely controlled, the atmosphere is now the main source of toxic organic pollutants to the Great Lakes"***
>
> (Raymond Hoff, 1998, currently Director, Joint Center for Earth Systems Technology, University of Maryland)

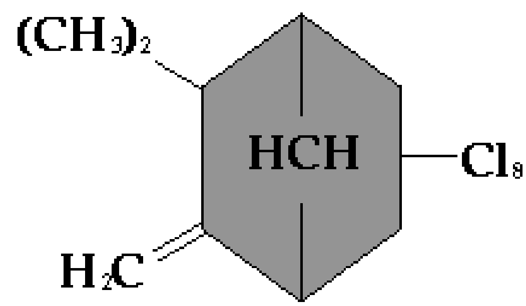
Both local and distant sources of pollutants can contribute to atmospheric loadings to the Great Lakes, shown in the adjacent figure. The Great Lakes airshed diagram illustrates the distance wind carried pollutants may travel in one, three or five days to reach the Great Lakes Basin. Factors such as weight and environmental persistence determine the distance pollutants will travel. New concepts such as airshed determinations are now allowing better evaluations and estimates of the total loadings to the Great Lakes.

The Great Lakes Airshed



Source: International Air Quality Advisory Board, 1988.

An excellent example of identified long-range pollutant transport has been developed for toxaphene. The adjacent figure identifies toxaphene use distribution (metric tons identified for each state) and back trajectories showing potential sources of toxaphene to an air-monitoring site at Egbert, Ontario. The trajectory corresponds to the five highest concentrations[5].

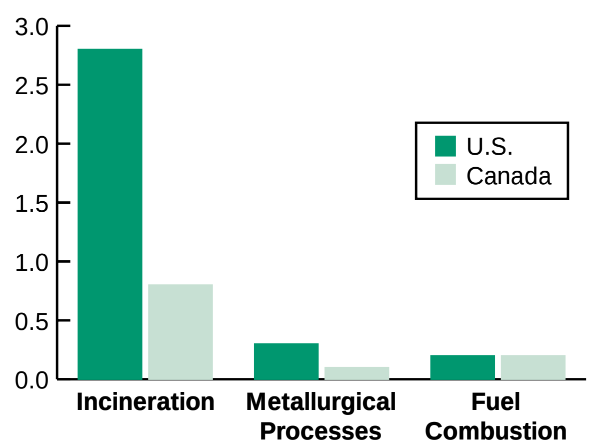


Source: Voldner & Schroeder, 1989.

The International Air Quality Advisory Board of the International Joint Commission has found that significant emissions of persistent toxic substances originate from a variety of different source types and a broad geographical range of locations. The largest source that contributes to Dioxin deposition is incineration, illustrated in the adjacent figure. Also, individual persistent toxic substances exhibit distinct behavior in the atmosphere with a wide range of estimated lifetimes/transport distances/re-emission rates. In a recent report the International Air Quality Advisory Board also revealed that:

- For Dioxins, it is estimated that approximately 77 percent of deposition to the five Great Lakes from air pathways originate from within the Great Lakes states and provinces.

Contribution of Different Source Sectors to Atmospheric Deposition of Dioxin to the Great Lakes (pg TEQ deposited/km2)(person/year)



Source: Michigan Department of Natural Resources, 1984 and U.S. Geological Survey, 1999 (data unavailable for 1991-97).

- In considering sources of atmospheric deposition of Dioxins to Lake Ontario, approximately 50 percent appear to originate from sources in close proximity to the lake, while the balance occurs from sources at a much greater distance (400-1500 km [250-930 miles]). A similar pattern occurs in Lake Erie and Lake Michigan.
- Regarding deposition to Lake Superior, transport of Dioxins from outside the region is relatively more important (40 percent of deposition is from sources between 400 - 700 km [250 and 435 miles]) distant, since there are few immediately adjacent upwind sources. This finding is also applicable to Lake Huron[5].

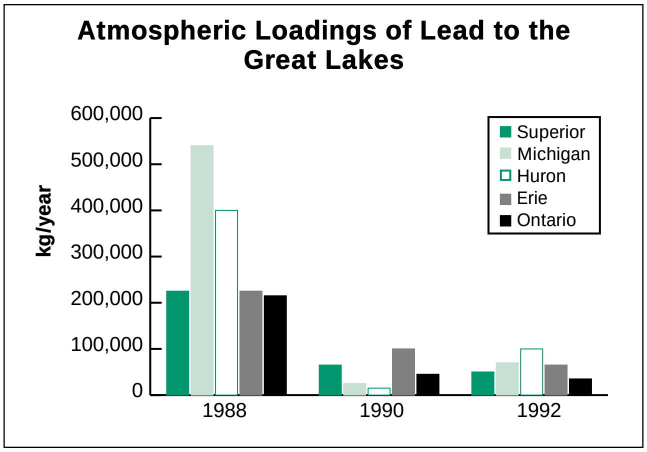
The table below identifies the contribution of atmospheric deposition of Dioxins to the Great Lakes from the Great Lakes states and provinces as compared to the rest of the United States and Canada.

Percent of Atmospheric Deposition of Dioxins to Lake Contributed by State or Province

State/Province Province	Superior	Huron	Michigan	Erie	Ontario	Great Lakes Average
Illinois	16	11	36	6	4	15
Indiana	13	12	27	8	4	13
Michigan	10	17	7	11	4	10
Minnesota	9	3	3	1	1	4
New York	4	4	2	8	35	11
Ohio	7	17	4	37	15	16
Pennsylvania	2	3	1	5	8	4
Wisconsin	2	1	2	0.3	0.3	1
Ontario	6	4	1	2	7	4
Total for Great Lakes States/Provinces	69	75	83	78	79	77
Total for all other U.S. States	29	23	16	21	20	22
Total for all other Canadian Provinces	2	2	1	1	2	1
Total for all other U.S. States and Canadian Provinces	31	25	17	22	21	23

Source: International Air Quality Advisory Board, 1999.

A study on Dioxin fallout in the Great Lakes, conducted by the Center for the Biology of Natural Systems at Queens College of New York, found 1329 sources that could contribute to the loading of Dioxins by air to the lakes. Medical waste incinerators, municipal solid waste incinerators, pulp and paper mill, iron sintering plants and cement kilns that burn hazardous waste can all contribute dioxins to the air.



Besides toxaphene and Dioxins, many other pollutants of concern are transported by air. Among these hazardous air pollutants are PCB, DDE, lead and mercury compounds, lindane, chlordane, polycyclic organic matter, and cadmium compounds.

By 1992 all the Great Lakes had experienced atmospheric loadings of lead less than 25 percent of those in 1988, as identified in the adjacent figure.

Understanding the pathways of pollutants by air is a complex process. So far, attempts to model systems, study patterns and estimate amounts deposited versus amounts released have raised as many questions as answers.

PHYSICAL TRENDS

Great Lakes policy has expanded from one that was focused primarily on chemical pollution toward a broader view that also encompasses physical and biological threats, including habitat destruction and exotic species introduction. In the 1992 National Water Quality Inventory Report to Congress the U.S. Environmental Protection Agency reported that 95 to 100 percent of the rivers and inland lakes assessed in Michigan received a "good" rating. However, there are still problems that remain. The major problems associated with Michigan rivers include siltation, metals and bacteria contamination. Many of these issues relate directly to the physical aspects of the Great Lakes watershed.

Land Use[12]

The Great Lakes Basin is home to more than 33 million people. Four-fifths of this largely urban population live in 17 metropolitan areas (11 in the United States and 6 in Canada). The United States basin population declined during the 1980s but has now stabilized. The Canadian population, however, has increased dramatically in Ontario over the past 20 years. Although the built environment constitutes less than 10 percent of the land area of the basin, most of this development is situated on or near the shores of the Great Lakes or on major tributaries.

Ontario's population is projected to increase by about 2 million people (20 percent) over the next 20 years. In contrast, the United States portion of the basin will likely see only limited population growth. The long-term trend of redistribution of economic activity and population from the older industrialized regions of the Great Lakes Basin to new and expanding regions elsewhere is moderating.

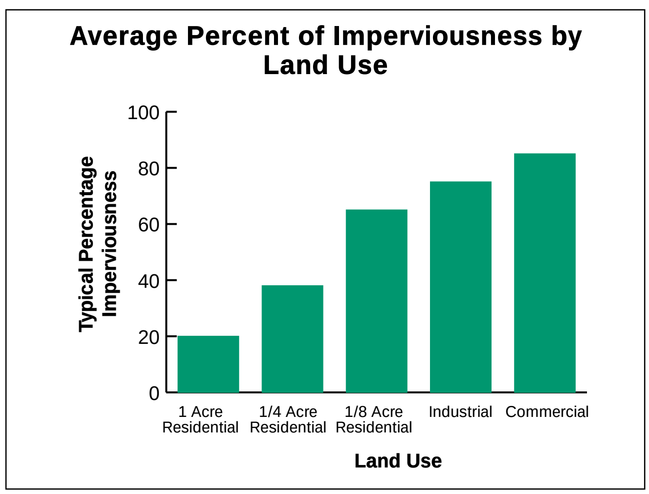
Traditional urban development that was once characterized by high population densities and, therefore, more efficient city services has virtually disappeared. The modern age of the automobile has facilitated widespread low-density urban and suburban growth over the last half century. This is the predominant pattern of development on both sides of the border. Land-use projections for the state of Michigan, for example, indicate that a state population increase of less than 12 percent may result in as much as an 87 percent increase in new developed land by the year 2020. A 6 percent population increase in southeastern Michigan alone is expected to result in a 40 percent increase in land consumption during this same period. There has also been a significant trend in the basin toward the extensive construction of seasonal "second homes" or recreational cottages. This trend is now shifting towards more permanent, year-round residences in rural areas.

The retreat of industry from its traditional location along the nearshore presents new opportunities for waterfront and harbor redevelopment as communities become involved in efforts to reuse waterfront areas for public and commercial uses. Redevelopment of former industrial sites presents opportunities for high-technology manufacturing, commercial service, residential or leisure or some mix of these activities which, presumably, reduces development pressure of "green space" in rural areas. There are, however, costs and environmental hurdles associated with cleaning up and restoring these sites that pose difficult challenges to governments and interested communities alike.

About a third of the land in the Great Lakes Basin is used for agriculture, with usage concentrated in the southern half of the basin. Nearly three-quarters of the basin's agricultural lands are on the United States side. In parts of the basin, agriculture-related sediment, pesticide, and nutrient loading of the Great Lakes tributary rivers is a leading cause of nonpoint source pollution, diffuse runoff from farms, concrete surfaces, golf courses, and the like. There is a trend towards fewer but larger farms with more intensive crop production and less land overall in agricultural production. From 1981 to 1992 basin farmland declined by almost 10 percent and cropland by almost 6 percent. The conversion of agricultural land to urban development, in addition to other competitive pressures, is causing a shift of agricultural activities to areas with less productive soils, shorter growing seasons, and greater distances to major markets. Land-use conflicts, especially the conversion of farmland to urban sprawl, will continue to be perhaps the greatest threat to the long-term viability of the agricultural sector.

An important trend that researchers are now trying to better understand is increased impervious surfaces on the landscape. Impervious cover can be defined as average surface in the urban landscape (including roads, streets, sidewalks, parking lots and rooftops) that can not effectively absorb or infiltrate rainfall. Impervious surfaces can have a significant negative impact on water quality by increasing the amount of runoff and pollutants carried by stormwater.

The level of imperviousness in a watershed is related to land use due to the transition from natural land use to residential, commercial, and industrial development. The hardening of the land surface decreases infiltration of water through the soil. Natural land cover allows precipitation to infiltrate where hardened surfaces increase runoff.



Source: U.S. Department of Agriculture, Natural Resources Conservation Service, 1983.

Research suggests that there is a threshold to the amount of impervious cover that can occur within a watershed before stream quality declines. Most researchers have found that water resource degradation consistently occurs at watershed impervious levels between 10 and 20 percent, and significant degradation begins at about 30 percent. In southeast Michigan between 1995 and 2020, the region projected population growth is 8 percent, while urban land is projected to increase 40 percent. As a result, the region's degree of imperviousness is expected to increase from 11 percent in 1995 to 20 percent in 2020, assuming local land use plans are fully implemented[13]. A recent effort in the Grand Traverse Bay watershed showed an overall percent of imperviousness to be below 10-20 percent. However, a number of subwatersheds have impervious surface at greater than 10 percent[14].

Efforts across the nation are identifying potential tools for local officials to consider when trying to address the long-term implications of increased imperviousness. These include zoning tools, information (education) and transfer at development rights.

Fish and Wildlife Habitat[15]

Wetland loss changes the biological and chemical make-up of the waters, which pass through them to the open waters of the Great Lakes. The adverse effects to wetlands from dredging, draining, diking, pollution (particularly sedimentation), hydrologic impacts (increased flooding response of streams and diminished flows during dry periods) and water level management have contributed to degradation of Great Lakes water quality. These adverse effects also have contributed to the decline of fish and wildlife populations dependent on the coastal and river mouth areas of the Great Lakes.

Pressures on land and water resources for economic development, including recreational use, must be balanced with restoring and maintaining the ecological integrity of our natural systems. Regulatory programs at both the state and federal level work to stem the loss of wetlands. Voluntary conservation programs encourage willing landowners to restore and protect wetlands and other habitats on their properties.

The wetlands and shorelines that existed in the Great Lakes Basin are only a fraction of the system that existed two centuries ago. The quantity, quality, and relative distribution of wetlands have changed dramatically as a result of the logging era, agricultural development, mining, road construction and urban development. Natural processes, such as succession and fluctuation in water levels of the Great Lakes, also affect the type and distribution of wetlands.

A comparison of pre-settlement vegetation records with current land cover maps suggests that Michigan has lost 28 percent of its wetlands, with the greatest loss occurring in the southern Lower Peninsula. In fifteen counties, more than 50 percent of wetlands have been lost and many remaining wetlands have been degraded. In counties that had significant amounts of coastal wetlands associated with Saginaw Bay, Lake St. Clair, and Lake Erie, more than 75 percent of historic wetlands have been lost[16]. Wetland loss is highest among wetland types that were most easily drained or altered. For example, Michigan has lost over 99 percent of its coastal wet prairies, and those remaining are scattered, small fragments of what once was.

Trends strongly indicate that continuing losses of coastal wetlands occur in some areas of the Great Lakes. Residential and commercial areas are expanding; agricultural lands are declining. Since the 1700s, the Great Lakes Basin has lost 34.9 million acres (almost 60 percent) of the pre-European settlement coastal wetlands.

An increasing awareness of the function of wetlands and their value to society has lead to increased efforts to protect and restore these important habitats. Wetlands help to improve water quality by filtering pollutants and trapping sediments. Wetlands can help to reduce storm and flood damage, and recharge groundwater. Many of Michigan's plant and animal species are dependent upon wetlands. Wetlands have recreational and aesthetic value that contributes to tourism and economic growth. A couple of recent efforts to protect and restore coastal wetlands are:

- The U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, U.S. Coast Guard and the Michigan Departments of Natural Resources and Environmental Quality recently participated in a multi-agency winter navigation agreement that will help protect the St. Marys River and more than 13,300 acres of coastal wetlands. In the agreement, there are provisions to protect more than 75 miles of riverine habitat and wetlands from the effects of the early navigation season.

Extent of Wetland by Type. Based on Michigan Resource Information System Data for 1978 (corrected)

Wetland Type	Acres	Percent of Land Area
Lowland Hardwoods	2,484,328	6.7
Lowland Conifers	1,825,978	4.9
Wooded Wetlands	259,456	0.7
Scrub/Shrub Wetlands	1,182,868	3.2
Aquatic Bed	60,251	0.2
Emergent Wetlands	419, 109	1.0
Unvegetative Flats	7,773	0.02
Total	6,239,763	16.72

Source: Department of Environmental Quality. 1998.

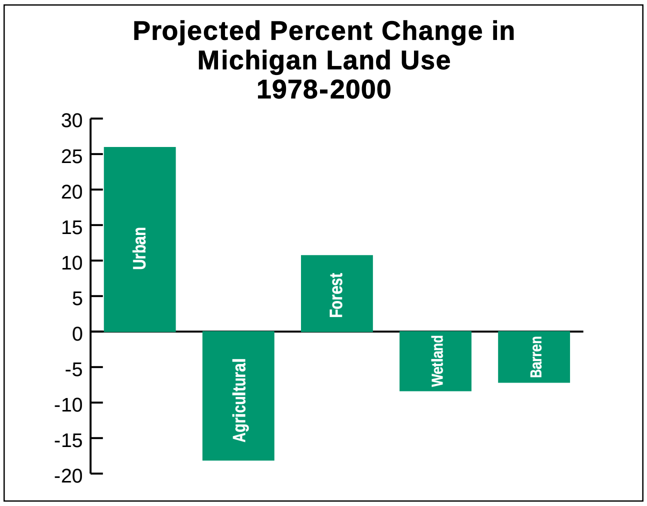
- Through partnerships among government agencies and conservation organizations, more than 1,000 wetland restoration projects totaling more than 5,000 acres have been completed on private property over the past several years. Partners, including the U.S. Fish and Wildlife Service, Michigan Department of Natural Resources, local Conservation Districts, Natural Resources Conservation Service, Ducks Unlimited, Pheasants Forever, and the Michigan Wildlife Habitat Foundation, have contributed resources to work with landowners in a voluntary effort to restore drained wetlands.

- The U.S. Department of Agriculture, Natural Resource Conservation Service is involved in three programs that provide technical and/or financial assistance for wetland restorations. Through the Wetland Reserves Program, Natural

Resource Conservation Service can purchase conservation easements from willing landowners to restore and protect wetlands that have been converted or degraded. Conservation easements allow long-term or permanent protection of wetlands. Currently, 16,000 acres in Michigan are under conservation easements and are presently being restored.

- The North American Waterfowl Management Plan is an international effort to restore waterfowl populations. Through diverse partnerships involving federal, state and provincial governments, corporations, private conservation organizations and others, key waterfowl habitats are identified and conserved. The Saginaw Bay is a focus area for current efforts. Recently, Ducks Unlimited received funding from the North American Wetlands Conservation Act on behalf of its partners to conserve wetlands and associated habitats in the Saginaw Bay watershed. Thus far almost 1,200 acres of wetlands and associated uplands have been acquired for public ownership and over 2,600 acres of wetlands and associated uplands have been restored.

Encroachment on the Great Lakes shoreline by agriculture, recreation, and urban/industry has become a major limiting factor for Great Lakes coastal habitat. Almost one-half of the globally rare species and communities in the basin, such as piping plover, Pitcher's thistle, Lake Huron tansy, Houghton's golden rod and others, require the coastal areas as primary habitat. Approximately 34 percent of the bald eagle's shoreline habitat is unsuitable for nesting which could be related to almost one-half of Michigan's human population residing in the coastal counties.



Source: Michigan Society of Planning Officials, 1995.

Future land use must strike a balance between economic and environmental interests, and consider both short-term and long-term benefits and consequences. The future of wetlands, and other important habitats, is dependent upon striking this balance among competing land use and long-term environmental health. With a human population that has grown nearly 14 percent from 1970 to 1991, the impacts of changing land use patterns will continue to influence the Great Lakes ecosystem. Urban land use continues to grow at a rapid rate and agricultural land use decreases as more farms are sold for development. While each of these land use changes may have a significant impact on the local environment, cumulatively, these changes will have a dramatic impact on the Great Lakes watershed.

Urban development into agricultural lands, and a desire by landowners to own large land parcels, has led to the loss of agricultural land at a rate of 10 acres/hour.

If this trend continues, the Michigan Society of Planning Officials predicted that urbanized land in Michigan would increase by 63-87 percent between 1990 and 2020. This trend can be seen in the adjacent figure.

Changes in practices associated with land use can also adversely impact the Great Lakes. Consolidation of farm fields and tillage practices may lead to increased sedimentation and nutrient loading into streams. Excessive use of lawn chemicals may also pollute waterways. Increased fragmentation of the landscape may adversely affect wildlife.

Positive steps, including local planning, will need to be taken to minimize potential adverse impacts from land use changes. Incentives for voluntary habitat restoration and protection on private property should continue. Efforts to reduce urban sprawl include redevelopment of brownfields to stimulate activity in urban areas. Some new communities cluster homes and other development to maintain natural areas. More of these types of development are needed to help preserve remaining open areas, including farmlands.

Another trend is taking hold - increased awareness of the importance of critical habitat. With an increasing knowledge that our land use decisions can adversely affect the Great Lakes ecosystem and that coastal habitats are crucial to many migratory birds and permanent wildlife, private groups such as The Nature Conservancy, The Rails-to-Trails Conservancy, Leelanau Conservancy, and many others have partnered with state and federal agencies, local communities, educational institutions and several other public entities to ensure the protection of crucial lands. The Leelanau Conservancy, among others, has purchased easement rights for land in northern Michigan in order to prevent future development on unique areas. These partnerships have provided new sources of funds and other assistance that benefit lands with important habitat values. Both the public and private sectors have begun to recognize their responsibility in securing the valuable landscapes for future generations to inherit. There are now over 40 organizations working to preserve and protect Michigan's natural areas. Working together, individuals, organizations, businesses, and government agencies can increase awareness and understanding of wetlands, shorelines, and other habitats, and take action to restore and protect those habitats for future generations.

Lake Levels[12]

Great Lakes waters are composed of numerous aquifers (groundwater) that have filled with water over the centuries, waters that flow in the tributaries of the Great Lakes, and waters that fill the lakes themselves. Although the total volume in the lakes

Approximate Season Depth Changes in Great Lakes

Ontario	3 meters	June/July
Erie	2-3 meters	June/July
Michigan/Huron	2 meters	June/July
Superior	1 meter	August/Sept.

Source: Cruising the Great Lakes. 1999.

is vast, on average less than 1 percent of the waters of the Great Lakes is renewed annually by precipitation, surface water runoff, and inflow from groundwater sources.

Lake levels are determined by the combined influence of precipitation (the primary source of natural water supply to the Great Lakes), upstream inflows, groundwater, surface water runoff, evaporation, diversions into and out of the system, and water level regulation. Because of the vast water surface area, water levels of the Great Lakes, even with large variations in precipitation and runoff, remain remarkably steady, with a normal fluctuation ranging from 0.3 to 0.6 meters (12-24 in.) in a single year, shown in the table above. Climatic conditions control precipitation (and thus groundwater recharge), runoff, and direct supply to the lakes as well as the rate of evaporation. These are the primary driving factors in determining water levels.

The U.S. Army Corps of Engineers has water level records for the period from 1918 to 1999, during which there were several periods of extremely high and extremely low water levels and flows. Exceptionally low levels were experienced in the mid-1920s, mid-1930s, and early 1960s. High levels occurred in 1929-30, 1952, 1973-74, 1985-86, and 1997-98. Studies of water level fluctuations have shown that the Great Lakes naturally respond to periods of above average, below-average, or extreme precipitation, water supply, and temperature conditions. The effects of existing control structures, diversions, and dredging on levels are minor in comparison.

Great Lakes levels respond to climatic variability, as illustrated by the impact of high water levels in the early 1950s and mid-1980s and of low water levels in the 1930s and mid-1960s. Significant variability will continue whether or not human-induced climate change is superimposed on natural fluctuations. An example of how quickly water levels can change in response to extreme climatic conditions is the period 1998-99, when the water levels of Lakes Michigan and Huron dropped 0.64 meters (25 in.) in 12 months.

Part of the reason for the dramatic drop in Lakes Michigan and Huron, and all of the Great Lakes overall, was the low precipitation in the Lake Superior region during the winter months of 1998-99, causing less water to runoff into the lake. Additionally, warmer air temperatures throughout the Great Lakes during 1998-99 caused warmer water temperatures that increased evaporation rates, contributing to lower lake levels. While this may be a positive change for coastal areas such as wetlands, algal blooms were also more common during this time period due to the higher water temperatures. Boaters experienced high maintenance due to shallow waters, which caused marinas to extend their docks or dredge or risk losing business. As a result of the present low water levels beaches expanded to widths not seen in over 30 years.

Measurements taken in July of 1998 at 100 feet deep in Lake Superior showed a significant increase in water temperatures compared to past recording. It is speculated based on this data, due to warmer average air temperatures on a year round basis, one of the world deepest freshwater lakes was beginning to warm up[17]. This increase in temperature could have a detrimental effect on the ecosystem of the lake. More exotic species would be able to survive with warmer temperatures and cold water fish populations would decline.

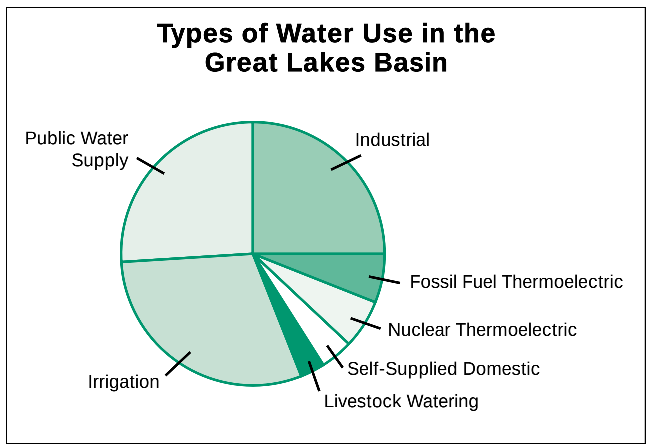
Water Uses[12]

The Great Lakes Commission has conducted a preliminary examination of water use data (1987-93) in the Great Lakes Basin. Water uses comprise two categories: consumptive uses and removals. Close to 90 percent of withdrawals are taken from the lakes themselves, with the remaining 10 percent coming from tributary streams and groundwater sources. An estimated 5 percent of the water withdrawn from the Great Lakes is consumed and is therefore lost to the basin. In 1993, consumptive use in the Great Lakes Basin was estimated to be 116 cubic meters per second (4,096 cubic feet per second) as compared to withdrawals of about 2,493 cubic meters per second (88,000 cubic feet per second). The 1993 consumptive use in the Great Lakes Basin can be summarized as follows:

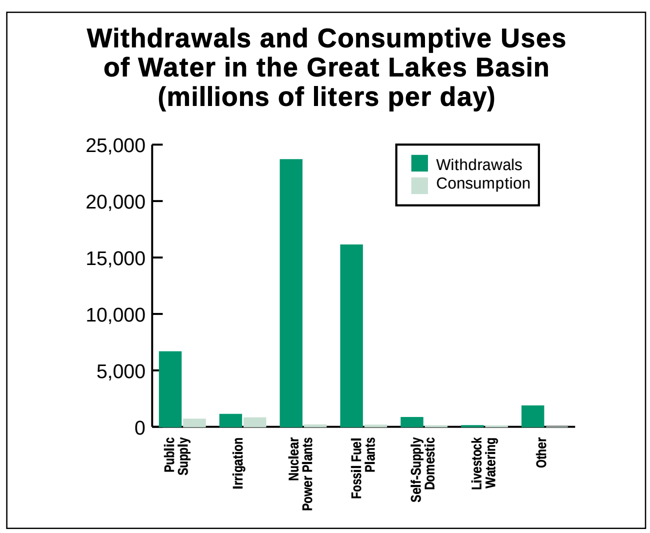
- *By country*: In total, consumptive use is 36 percent for Canada and 64 percent for the United States, with per capita consumptive use being approximately equal for the two countries.

- *By jurisdiction*: The largest nonconsumptive water user is Ontario at 29 percent followed by Michigan at 22 percent; Wisconsin at 21 percent; Indiana at 7 percent; New York, Quebec, and Ohio at 6 percent each; Minnesota at 2 percent; and Pennsylvania and Illinois at less than 1 percent each.

- As identified in the adjacent figure regarding the types of water use, the largest Great Lakes water use is irrigation followed by public water supply, industrial use, fossil fuel, thermoelectric and nuclear thermoelectric uses. The adjacent figure regarding withdrawls and consumptive uses identifies



Source: Great Lakes Commission.



Source: Michigan Department of Natural Resources, 1984 and U.S. Geological Survey, 1999 (data unavailable for 1991-97).

current water uses in the Great Lakes basin, including water withdrawals and consumptive uses.

Based on a very preliminary analysis, growth in withdrawals and consumptive uses in the basin appears to have slowed. In the International Joint Commission's 1985 Great Lakes Diversions and Consumptive Uses report, consumptive use in the Great Lakes Basin was estimated to be in a range of about 82 cubic meters per second (2,900 cubic feet per second). This is a significant reduction from the 1980 estimates of 159 cubic meters per second (5,600 cubic feet per second). Information from the Regional Water Use Database suggests that consumptive use in 1993 was still near the middle of that range, which would be consistent with a more general leveling off of water use in North America.

The International Joint Commission developed tentative projections into trends in water use and their impact on potential future water demands. These projections were derived from a simple extension of trends established over the previous decade. Results, presented below, extend to the years 2020-21. The Commission cautions that projections beyond two decades are highly speculative.

- ***Thermoelectric Power Use*** — In the United States, Great Lakes withdrawals have remained relatively constant since 1985 and are expected to remain near their current levels for the next few decades. In Canada, modest increases are expected to continue along with population and economic growth.

- ***Industrial and Commercial Use*** — In the United States, industrial and commercial Great Lakes water use has declined. A similar trend is evident in Ontario. Expected use to gradually decline through 2020.

- ***Domestic and Public Use*** — In the United States, Great Lakes water use for domestic and public purposes generally increased from 1960 to 1995 and is expected to climb gradually through 2020. Because of aggressive water-conservation efforts in Ontario, a modest downward trend established in recent years is expected to continue.

- ***Agriculture*** — In the United States, Great Lakes water used for agriculture increased fairly steadily from 1960 to 1995. In Canada, the rate of increase was somewhat larger. Combined projections indicate a significant increase by 2020.

- ***Total Water Use*** — If current trends continue, total water use in the Canadian portion of the basin is expected to increase by close to 20 percent between 1996 and 2021. A decrease of about 2 percent is expected in the United States' portion of the basin between 1995 and 2020, although the United States' use is expected to begin rising again after that time. The combined projections indicate a modest increase of about 5 percent for the entire Great Lakes Basin between 1995-96 and 2020-21.

Great Lakes Diversions[12]

Diversions have been constructed to bring water into the Great Lakes system from the Albany River system in northern Ontario at Longlac and Ogoki shown in adjacent table. They also have been constructed to take water out of the system at Chicago and, to a much lesser extent, through the Erie Canal. At the present time, more water is diverted into the system than is taken out. Water is also diverted around Niagara Falls for hydroelectric power generation, and water is diverted from Lake Erie to Lake Ontario through the Welland Canal.

Recent public concern has been focused on the potential movement of freshwater in bulk beyond the Great Lakes Basin. To date, no regular trade has begun to ship water in bulk from the Great Lakes Basin or from North America as a whole. For almost two decades, however, entrepreneurs have actively pursued foreign markets. Alaska, Newfoundland, and Quebec currently are entertaining proposals to export freshwater in bulk by ocean tankers.

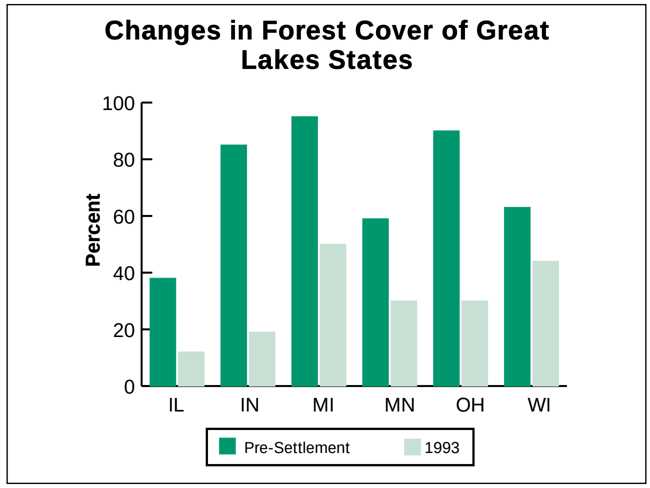
Existing Diversions	Date Operational	Average Annual Flow	
		CM/S	CF/S
Interbasin			
Longlac, Ontario (into Lake Superior)	1939	45	1,590
Ogoki, Ontario (into Lake Superior)	1943	113	3,990
Chicago, Illinois (out from Lake Michigan)	1900	91	3,200
Forrestport, New York (out of Lake Ontario)	1825	3	120
Portage Canal, Wisconsin (into Lake Michigan)	1860	1	50
Pleasant Prairie, Wisconsin (out of Lake Michigan)	1990	0.1	5
Akron, Ohio (out of and into Lake Erie)	1998	0.1	6
Intrabasin			
Welland Canal	1932	260	9,200
New York State Barge	1918	20	700
Canal (Erie Canal)			
Detroit	1975	4	145
London	1967	3	110
Raisin River	1968	0.7	25
Haldimand, Ontario	1997	0.1	2

CM/S = Cubic Meters/Second CF/S = Cubic Feet/Second
Source: International Joint Commission, 1999.

BIOLOGICAL TRENDS

Forests

The Great Lakes states now have the most forests owned and managed in the lower 48 states. Since the settlement of Michigan, forested land cover has decreased from 95 percent to 50 percent. The adjacent figure identifies the difference between forested lands before settlement and those that existed in 1993. From the 1970s to 1990s, forest area increased modestly with the reversion of marginal agricultural land to forests. This increase in forest area is evident in the last several statewide forest resource inventories. Forested area has increased substantially and the tree size in some species has grown significantly. Over the past forty years, the margin by which forest growth exceeds harvest has increased even while harvest has expanded by about 50 percent. In addition, several forest-dependent species have experienced rising population levels in the Great Lakes states. During the 1980s, large corporations invested $4.5 billion in new and expanded plants in pulp and paper and in the building-products sector.



Source: Environmental Protection Agency, 1993.

Fish and Wildlife

From a fisheries habitat perspective, most of Great Lakes' streams and watersheds have been altered by human activities, including dam construction, dredging, filling, road construction and others. These activities have had major impacts on the quality of the fisheries resources found in the Great Lakes Basin. Michigan has extensive, high quality fishery resources in the Great Lakes and inland waters. There are 70 state and municipal harbors along the Michigan Great Lakes coastline, and more than 600 fishing and sailing charters are in operation. In 1993, it was estimated that 886,000 Michigan anglers spent 11 million days fishing Great Lakes waters. Also in 1995, commercial fishing in United States waters of the Great Lakes harvested about 14.6 million pounds of lake whitefish, chubs, yellow perch, lake trout, salmon and other species with a value of approximately $10.8 million.

Due to the banning of PCBs and DDT, and the resulting lower levels of contaminants in the environment, fish eating birds are thriving again. The bald eagle has now been removed from the endangered species list. There is still a

Threatened and Endangered Great Lakes Wildlife	
Kirtland's Warbler (Singing Males)	
Lower Peninsula	885
Upper Peninsula	19
Ontario	1
Total	905
Piping Plover (Pairs)	
Michigan	31
Wisconsin	1
Total	32
Bald Eagle (Occupied Nests)	
Upper Peninsula	180
Lower Peninsula	135
Total	315
Peregrines (Nesting Pairs)	8
Wolves	175
Wolf Packs	30

Source: Michigan Department of Natural Resources, 1999.

decrease in nesting sites due to habitat loss. Peregrine falcon populations are also soaring which has led to its removal from the Endangered Species list. Cormorants are flourishing.

Wolf populations have increased in the Upper Peninsula from levels near extirpation in the 1970s. Based on the winter wolf survey of 1998-99 conducted by the Michigan Department of Natural Resources, there are at least 174 wolves in at least 30 packs shown in the adjacent table, scattered across the Upper Peninsula, up from last year's count of 140[18].

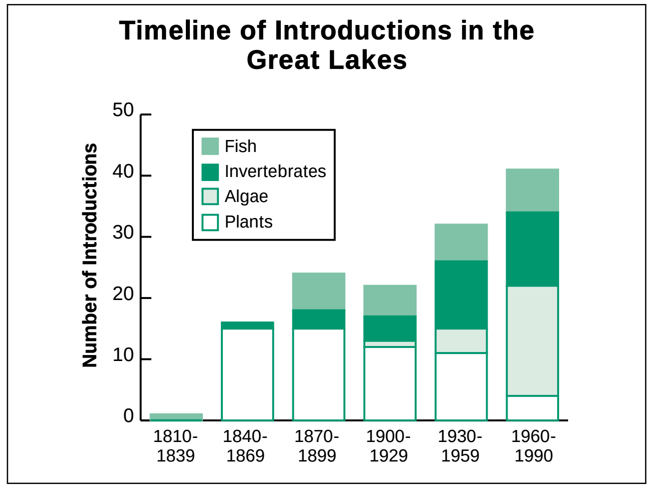
Piping plovers are shorebirds that only nest on Great Lakes beaches. Due to encroachment, increased populations, and pollution, this shorebird's populations plummeted to only 13 pairs found in the region. Down from 150-200 pairs once counted in Michigan alone, plovers are now recovering. During the summer of 1999, 30 pairs were counted in the Great Lakes[19].

Nonindigenous Aquatic Nuisance Species

Unintended introductions of nonindigenous aquatic nuisance species or "exotics," such as the sea lamprey and zebra mussels, have played a major role in modifying aquatic ecosystems of the Great Lakes. Second only to loss of habitat, exotic species are severely impacting native species. Freed from competitors, predators, parasites and pathogens that regulated populations in their native environments, exotic species are considered among the most severe forms of habitat alteration and a major cause of continuing loss of biological diversity in the Great Lakes ecosystem. Lack of natural controls in a new habitat can allow the new species to grow at or near its potential exponential growth rate. Aquatic nuisance species also compete for food with many native species.

The greatest number of species introduced into the Great Lakes coincides with the expansion of the St. Lawrence Seaway in 1959. This expansion allowed larger and more ships to pass through the seaway, shown in the adjacent figure. Over 144 new species have been introduced into the Great Lakes Basin since the 1800s.

Intercontinental shipping is now faster due to increased technology, and water quality is improving in many areas of the world. These changes allow zebra mussels, ruffe, gobies and other pests to survive the journey in ship ballast water from Eurasia to the Great Lakes. In addition, water used for many purposes, including food processing, bait industry, private aquaculture and the aquarium trade, are all potential pathways of introduction of exotic species.



Source: Mills, E. et al., 1993.

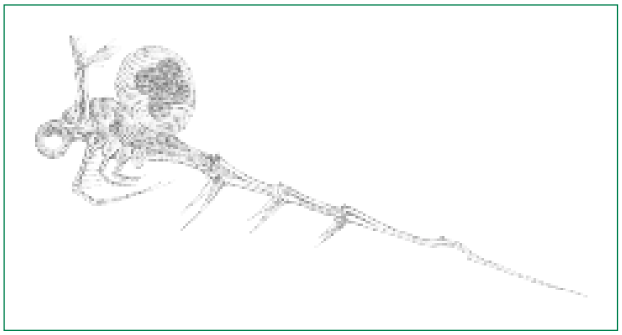
Zebra mussels were first discovered in Lake St. Clair during the spring of 1988. Researchers believe they were picked up in the ballast of a ship that had visited Eastern Europe where this mollusk is common and then released into the Great Lakes. Since then the mussels have spread throughout all five Great Lakes and into the Mississippi, Missouri, Tennessee, Hudson and Ohio River basins and beyond. Large water users in the Great Lakes, including municipalities and industries, pay an average of $360,000 per year to control zebra mussels, with documented cumulative costs of $120 million from 1989 to 1994.

Native clams have been decimated in some parts of the Great Lakes due to food competition caused from the enormous filter feeding capacity of the zebra mussel. In addition, zebra mussels affix themselves to the shells of clams, eventually leading to death. However, some native species find their own niche in the system enabling their populations to survive. Native clams have been found in wetlands with specific sediment types and water temperature that allows for the coexistence of various species. A wetland in Lake Erie supports a small population of clams with two other coastal sites[15].

Another established nuisance species is the Eurasian ruffe. The ruffe is a small perch-like fish that is believed to have been introduced by ballast water into the St. Louis River near Duluth, Minnesota. They feed on the eggs of whitefish and compete with more desirable fish such as yellow perch. In Lake Superior, yellow perch are most affected by the presence of ruffe. This species has now been documented in the Thunder Bay region of Lake Huron.

The round and tubenose goby originate in the Black and Caspian Seas. These fish are small but abundant and feed mainly on bivalves, amphipod crustaceans, small fish and fish eggs. The loss of small fish and fish eggs, and competition with other desirable species is what makes these species harmful.

The spiny water flea, *Bythotrephes cederstroemii*, also believed to have been introduced from ballast water, competes with young fish for food. The spiny water flea has been known to have significant impacts on a lake's plankton even though it is small in size. Many small and juvenile fish will not feed on the spiny water flea because it is so well protected by a barb-like armor. Because the spiny water flea rapidly reproduces and roams relatively unimpeded, it can monopolize food supplies and alter energy flows within aquatic systems.



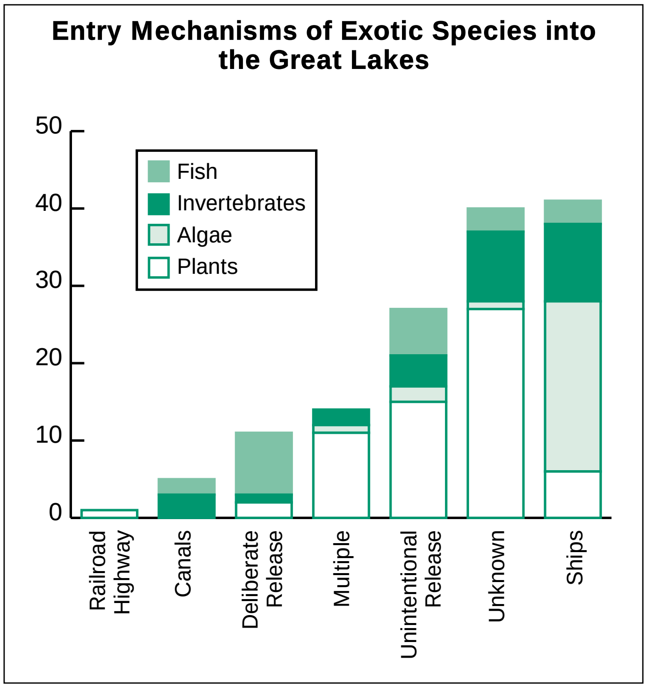
Spiny Water Flea

Another species *Cercopagis pengoi*, a crustacean similar to bythotrephes, has recently appeared in large numbers in Lakes Ontario and Michigan. It is believed to have been introduced via ship ballast. This species originates in the Caspian Sea in Eastern Europe. They feed on zooplankton impacting the ecosystem similar to the spiny water flea. Cercopagis can reproduce at high rates leading to large densities throughout the Great Lakes. It can produce up to 13 offspring at one time, reproduce numerous times throughout one season, and produce eggs that can remain dormant over winter and through harsh conditions. Cercopagis has a long spiny tail similar to the spiny water flea that creates difficulty in consumption for smaller fish.

Probably the most notorious exotic invader is the sea lamprey, which has been a serious problem in the Great Lakes for more than fifty years. Adult lamprey can kill up to 40 pounds of fish in just 12 to 20 months. Overfishing and lamprey predation in the middle part of this century drove lake trout to near extinction. Lake trout populations in northern Lakes Michigan and Huron are still under stress caused by lamprey predation.

The St. Marys River has been a major spawning area for the sea lamprey, which has been considered the source of increasing lamprey populations. It produces more sea lamprey than all other Great Lakes tributaries combined. Treatments have begun for the St. Marys River using a lampricide and a method of sterilizing males. Since the start of the extensive control efforts, Lake Superior has had a 90 percent reduction in sea lamprey populations due to the extensive control efforts in the St. Marys River and other efforts throughout the Lake Superior Basin. By combining the application of granular Bayer lampricide with trapping and a sterile male release technique, an 85 percent reduction is projected for Lakes Huron and northern parts of Michigan[20].

Nonindigenous aquatic species continue to pose a serious threat. While limited progress is being made to decrease the number of new exotics being introduced into the Great Lakes Basin, much remains to be accomplished. Some ships are now required to exchange their ballast water at sea, flushing out organisms and raising the salinity of the ballast water to kill freshwater organisms that might remain alive in the ballast tank. Although open-water exchange helps reduce the risk of exotics found in ballast tanks and sediments, it does not go far enough to ensure protection of the Great Lakes. A recent study predicts 17 additional introductions of animals from the Ponto-Caspian basin alone, many of which have broad salinity tolerance[21]. The adjacent figure identifies historical entry mechanisms for the introduction of exotic species to the Great Lakes.



Source: Mills, E. et al., 1993.

Other control methods such as heating the water, biocides, filtration, or passing the water through ultraviolet light are being studied. A study sponsored by the National Research Council identified the use of non-oxidizing biocides, such as glutaraldehyde, as a potential method for treating ballast water. Glutaraldehyde is an organic compound that is effective in eliminating a wide range of organisms. It is used by many industries because of its effectiveness in elimination of numerous organisms[22].

In 1996, the Council of Great Lakes Governors and the regional Great Lakes Protection Fund sponsored the Ballast Technology Demonstration Project to examine filtration technology to prevent the invasion of exotics. Past filtering practices such as coarse screens placed over sea chest intakes that leads to the ballast pump had not proved to be effective against the invasion of many small organisms such as zooplankton and other organisms in the larval stage. Experimental fine filtration technology has been developed to prevent the invasion of these very small organisms. Testing in salt and fresh water environments is underway to determine its effectiveness. Large-scale and rigorous projects aimed at demonstrating potential control will ultimately lead us to reducing the number of exotics entering the Great Lakes and water bodies around the world.

SUMMARY OF GREAT LAKES TRENDS

To summarize the state of the Great Lakes in broad terms, the general long-term trends are:

Chemical

Conventional Pollutants — Nutrient levels have decreased in the Great Lakes. Generally, the goals of the Great Lakes Water Quality Agreement had been achieved but recently some phosphorus levels have risen above objectives. Dissolved oxygen levels have improved. Chloride and nitrogen levels appear to be increasing.

Toxics — Atmospheric deposition of toxics is now paramount in the Great Lakes ecosystem. The concern regarding atmospheric deposition highlights the importance of controlling sources on a local, national, and global scale. Direct water discharges of toxics have been reduced across the Great Lakes Basin. For many toxics we have seen a general decrease in concentrations in our waters over the last 20 years. Open water sediment concentrations have decreased. Localized problems and some chemical specific issues still exist as evidenced by fish consumption advisories.

Hormone Disruptors — There is uncertainty that some man-made chemicals may be interfering with normal endocrine system functioning in humans, less so for animals. Considerable scientific research is required for specific chemicals, exposure, action mechanisms and testing.

Physical

Land Use — Loss of important ecological areas, including coastal wetlands, still occurs in some areas. Residential and commercial areas are expanding; agricultural lands are declining. However, forest area is expanding. Land use decisions continue to impact the quality of the Great Lakes ecosystem, especially coastal and nearshore areas.

Lake Levels — Recently, water levels in most of the Great Lakes have fallen dramatically since 1998. Most lakes are now significantly below their historic averages. Short-term water level projections are unsure, with levels possibly going lower. From a long-term perspective, water levels are lower than normal but above their historic lows.

Water Uses Growth of withdrawals and consumptive use in the Great Lakes Basin appears to have slowed which is consistent with a leveling off of water use in North America.

Diversions At the present time more water is diverted into the system than is taken out. Caution is warranted regarding future uses of Great Lakes water.

Biological

Forests Forested areas are increasing throughout Michigan. Forest growth has been exceeding harvest by about 50 percent over the past forty years.

Fish & Wildlife Some improvements in Great Lakes fisheries have been realized. Findings of lake trout natural reproduction are promising. However, stocking of many species is necessary. Contaminant levels in fish have decreased over the long-term but the rate of decrease has slowed. Great Lakes fish-eating birds have shown population increases, the important limiting factor being physical habitat.

Nonindigenous Aquatic Nuisance Species Habitat destruction and introduction of exotic species continue to be serious concerns. New introductions of nonindigenous species continue. Nonindigenous aquatic species such as the zebra mussel, ruffe, round goby, spiny water flea, sea lamprey and others cause significant ecological harm.

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John Engler, Governor; Russell J. Harding, Director

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