LAKE ERIE

LAKEWIDE
MANAGEMENT
PLAN

Lake Erie LaMP

Acknowledgements

Photo: Robin McLeod

The Lake LaMP Work Group, under the direction of the Lake Erie LaMP Management Committee, prepared the Lake Erie LaMP 2006 Report. Environment Canada and the U.S.EPA are the federal co-leads for the Lake Erie LaMP. The other agencies playing an active role in the process are:

Canada

- Fisheries and Oceans Canada
- FOCALerie (Federation of Conservation Authorities of Lake Erie)
- Health Canada
- Ontario Ministry of Agriculture and Food
- Ontario Ministry of the Environment
- Ontario Ministry of Natural Resources

United States

- Michigan Department of Environmental Quality
- New York State Department of Environmental Conservation
- National Oceanic and Atmospheric Administration
- Ohio Department of Natural Resources
- Ohio Environmental Protection Agency
- Pennsylvania Department of Environmental Protection
- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- U.S. Geological Survey

Binational Observers

- Great Lakes Fishery Commission
- International Joint Commission

Members of the Work Group, Management Committee, technical subcommittees, and the Public Forum contributed to the content of this report. The Work Group would like to specifically thank the following people for their efforts:

- Environment Canada – Sandro Leonardelli, Luca Cargnelli, Jennifer Vincent
- U.S.EPA – Elizabeth Murphy, Holly Wirick
- U.S. Geological Survey – Dan Button
- Pennsylvania Department of Environmental Protection – Jim Grazio
- Michigan Department of Environmental Quality – Shanna Draheim
- New York Department of Environmental Conservation – Robert Townsend
- Ohio Department of Natural Resources – Jeff Tyson
- Ohio Environmental Protection Agency – Julie Letterhos
- University of Windsor – Jan Ciborowski, Scudder Mackey
- FOCALerie – Matthew Child, Karen Maaskant, Teresa Hollingsworth
- Fisheries and Oceans Canada – Michael Whittle, Michael Keir
- Bio-Software Environmental Data – J. Fraser Gorrie
- National Oceanic and Atmospheric Administration – Stuart Ludsin, Stephen Brandt
- National Center for Water Quality Research, Heidelberg College – R. Peter Richards
- University of Waterloo – Scott Higgins
- Ontario Ministry of Environment – Todd Howell

Thank you to the Upper Thames River Conservation Authority for providing support on formatting and printing, and for showing utmost patience in dealing with last minute changes.

Finally, the Work Group and Management Committee would like to thank Jennifer Vincent, Environment Canada and Julie Letterhos, Ohio EPA who served as co-editors of the 2006 Report.

In keeping with the spirit of binational cooperation, the reader will note the alternation between Canadian and U.S. preferred spelling on a number of occasions.

Photo: Upper Thames River Conservation Authority

Cover photos:
Mike Weimer, U.S. Fish & Wildlife Service (child with fish, lighthouse)
Scott Gillingwater (beach)

Table of Contents

List of Figures

Photo: Lucas Foerster

List of Tables

Introduction

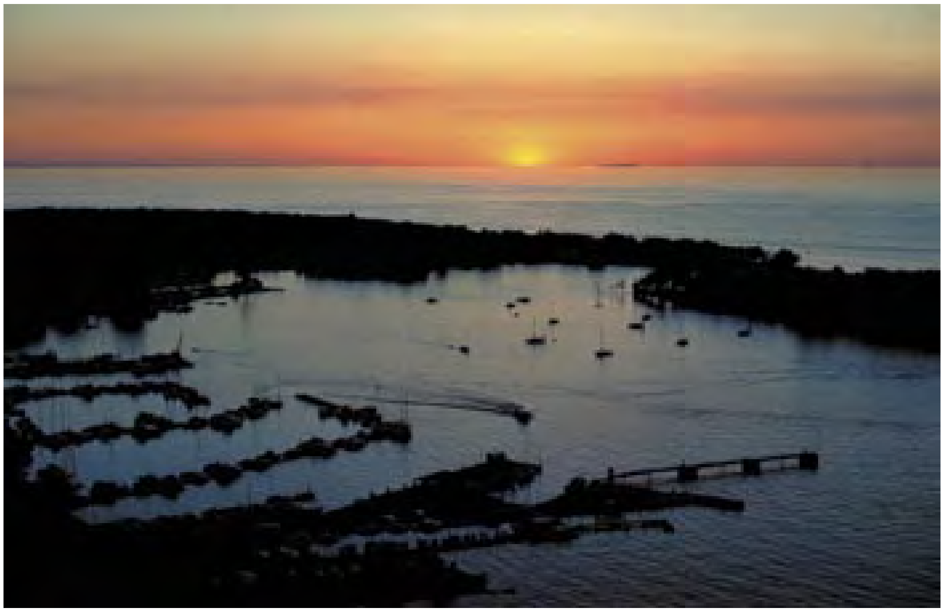


Photo: U.S. EPA Great Lakes National Program Office

One of the most significant environmental agreements in the history of the Great Lakes took place with the signing of the Great Lakes Water Quality Agreement of 1978 (GLWQA) between the United States and Canada. This historic agreement committed the U.S. and Canada (the Parties) to address the water quality issues of the Great Lakes in a coordinated, joint fashion. The purpose of the GLWQA is to "restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." Paramount to this goal was the protection of human health.

In the revised GLWQA of 1978, as amended by Protocol signed November 18, 1987, the Parties agreed to develop and implement, in consultation with State and Provincial Governments, Lakewide Management Plans (LaMPs) for lake waters and Remedial Action Plans (RAPs) for Areas of Concern (AOCs). The LaMPs are intended to identify critical pollutants that impair beneficial uses in the lake proper and to develop strategies, recommendations and policy options to restore these beneficial uses. Moreover, the Specific Objectives Supplement to Annex 1 of the GLWQA requires the development of ecosystem objectives for the lakes as the state of knowledge permits. Annex 2 further indicates that the RAPs and LaMPs "shall embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses...they are to serve as an important step toward virtual elimination of persistent toxic substances...."

The Great Lakes Water Quality Agreement specifies that the LaMPs be completed in four stages. These stages are: 1) when problem definition has been completed; 2) when the schedule of load reductions has been determined; 3) when remedial measures are selected; and 4) when monitoring indicates that the contribution of the critical pollutants to impairment of beneficial uses has been eliminated. These stage descriptions suggest that the LaMPs are to focus solely on the impact of critical pollutants to the lakes. However, the group of government agencies designing the LaMPs felt it was also an opportunity to address other equally important issues in the lake basins. Therefore, the LaMPs go beyond the requirement of a LaMP for critical pollutants and use an ecosystem approach, integrating environmental protection and natural resource management.

The LaMP process has proven to be a resource intensive effort and has taken much longer than expected. In the interest of advancing the rehabilitation of the Great Lakes, and getting more information out to the public in a timely manner, the Binational Executive Committee (BEC) passed a resolution in 1999 to accelerate the LaMP effort (BEC 1999). By accelerate, it

was meant that there should be an emphasis on taking action and adopting a streamlined LaMP review and approval process. The LaMPs should treat problem identification, selection of remedial and regulatory measures, and implementation as a concurrent, integrated process rather than a sequential one.

The BEC endorsed application of the concept of adaptive management to the LaMP process. The LaMPs employ a dynamic process with iterative elements, such as periodic reporting. Adaptive management allows the process to change and build upon lessons learned, successes, new information, changes in the lake and public input. The LaMP will adjust over time to address the most pertinent issues facing the lake ecosystems.

Working under the adaptive management concept, the BEC recommended that a LaMP be produced for each lake by April 2000, with updates every two years thereafter. The LaMPs were to be based on the current body of knowledge and state what remedial actions can be implemented now. Consistent with the BEC resolution, the Lake Erie LaMP 2000 was presented in a loose-leaf format with general tabbed sections that could be inserted into a three-ring binder. This format allowed the LaMP to be viewed as a working draft of the dynamic LaMP process and adding new material and removing outdated information could easily update the document. However, in 2002, rather than updating the LaMP 2000 binder, a separate stand-alone progress report was produced.

For 2004, aspects of the LaMP 2000 and LaMP 2002 are combined to better reflect the BEC concept of one working draft. The document is slightly reformatted to better accommodate updates on LaMP progress as well as maintain documentation of the main history that formed the baseline and direction of the LaMP. It will truly become "The Lake Erie LaMP," an ever-changing accounting of the goals and progress of the Lake Erie LaMP process.

The GLWQA directs that the LaMPs take an ecosystem approach to assessing problem definition and implementing remedial actions. This concept is evident throughout the Lake Erie LaMP. The environmental integrity of Lake Erie is dependent not only on various characteristics and stressors within the lake itself, but also on actions implemented throughout the Lake Erie watershed and beyond. Urban sprawl, shoreline development, climate change, the introduction of non-native invasive species, the use and destruction of natural lands and resources, the dominant agricultural and industrial practices within the lake basin, and long-range transport of contaminants from outside the basin all impact the health of Lake Erie.

The watershed approach has been widely accepted as a necessary practice to achieve environmental restoration and protection. Many of the RAPs take a watershed approach to restoring the beneficial uses impaired in their AOCs. The TMDL program in the U.S. uses a watershed approach to return all impaired streams to their designated use. Many other communities around Lake Erie have instituted watershed-planning efforts focused on improving their local waterways. The challenge of the LaMP is to extend those watershed-planning efforts to include a lake effect component as well. Some watersheds, such as the Maumee (OH) and the Grand (ON), have a more direct impact on Lake Erie than others, but in the big picture all tributaries ultimately contribute to lake conditions in some way. Conversely, some conditions in the lake (i.e. non-native invasive species, contaminants, water levels, etc.) may also be impacting the tributaries.

The LaMP provides a binational structure for addressing these environmental and natural resource issues, coordinating research, pooling resources, and making joint commitments to improve the environmental quality of the Lake Erie. The Lake Erie LaMP is a program in which ongoing efforts, some of which may be conducted independently of the LaMP, can be strategically synthesized. Some of these actions include: the State of the Lakes Ecosystem

Conference (SOLEC) efforts to develop Great Lakes indicators; the Lake Erie Millennium Network initiative to identify, prioritize and pursue research needs; the efforts of Canadian and U.S. conservation agencies in controlling non-point sources and agricultural land use management; the land acquisition and preservation efforts of environmental groups such as The Nature Conservancy and the Nature Conservancy of Canada; the pollution prevention based activities of the Great Lakes Binational Toxics Strategy; implementation of the Remedial Action Plans in the 12 Lake Erie areas of concern; the fishery management plan of the Great Lakes Fishery Commission's Lake Erie Committee; implementation of wildlife management plans; and the efforts of the Lake Erie Binational Public Forum and others encouraging stakeholders across the basin to become involved in the decision-making process to determine the future status of Lake Erie. The LaMP remains mindful of emerging issues that may need to be adapted into the LaMP management scheme.

The Lake Erie LaMP focuses on measuring ecosystem health, teasing out the stressors responsible for impairments, and evaluating the effectiveness of existing programs in resolving the stress by continuing to monitor the ecosystem response. The role of the LaMP, as a management plan, is to define the management intervention needed to bring Lake Erie back to chemical, physical and biological integrity, and to further define agency commitments to those actions. Although Environment Canada (EC) and the U.S. Environmental Protection Agency (U.S. EPA) are the lead agencies for the LaMP, it takes an array of federal, local, state and provincial agencies and stakeholders to successfully design and implement the Lake Erie LaMP.

Section 1: Executive Summary

Working under the adaptive management concept, the Binational Executive Committee (BEC) recommended that a LaMP be produced for each lake by April 2000, with updates every two years thereafter. Consistent with the BEC resolution, the Lake Erie LaMP 2000 was presented in a loose-leaf format, with general tabbed sections, that could be inserted into a three-ring binder. This format allows the LaMP to be viewed as a working document, easily adding new material and removing outdated information as needed.

It is important to understand that the Lake Erie LaMP is a management plan and not a state of the lake report. Biennial updates are meant to measure the progress under the LaMP work plan or present the results of research or assessment reports that were undertaken or initiated by or in collaboration with the Lake Erie LaMP. This revised document does not include reference to all actions that have occurred in the Lake Erie watershed since the 2004 report.

The Lake Erie LaMP has compiled and assessed a significant amount of information to determine the current problems in the lake, their sources, and the ecosystem objectives that must be achieved if the Lake Erie LaMP vision is to be obtained. It is now time to focus on implementation. What actions or programs are most important to protect and restore the lake? Who has the authority to implement those actions? Is additional funding needed and, if so, where will it come from? Is the LaMP management structure sufficient to achieve the Lake Erie vision? The LaMP work plan for the next two years will address these questions.

Photo: Upper Thames River Conservation Authority

The Lake Erie LaMP must finalize measurable indicators that identify the current state of the ecosystem relative to the desired state of the ecosystem, as described by the Lake Erie Vision and ecosystem management objectives. The Indicators Task Group has prepared an indicator matrix to better understand and organize the application of the proposed indicators. The matrix structure is based on the five habitat zones identified for the Lake Erie basin. The indicators are divided into two categories: pressure (including the management objectives and processes) and state. The matrix has been populated by candidate indicators proposed by respondents to a questionnaire. The next step is to refine the list of candidate indicators using selection criteria defined by the Task Group. The result will be a suite of indicators that meet the needs of the Lake Erie LaMP.

Concentrations of selected contaminants in bed sediment were further summarized. Results support the understanding that high levels of trace element and PAH contamination are not systemic throughout the basin (in both tributaries and open lake), but co-located with source areas such as urban-industrialized areas, creosote production and petroleum processing and refining. Median concentrations for all the trace elements were below threshold effect concentrations (TEC). Organochlorine pesticides (DDT, dieldrin, mirex, lindane, chlordane, hexachlorobenzene) and PCBs continue to persist in the sediments although they are detected less frequently than trace elements or PAHs. Localized high concentrations of these chemicals exist, but the median concentration never exceeded TEC.

Although considered inadequate to calculate total loadings to the Lake Erie Basin, evaluation of the U.S. Toxic Release Inventory (TRI) and the Canadian National Pollutant Release Inventory (NPRI) was done to estimate the amount of mercury released in the basin and the top contributing sources. From 1995 to 2003, over 69,000 kg (151,800 lbs) of mercury were reported released, primarily to air and onsite landfills or transferred to offsite sewage treatment plants. Waste management companies, electric services and chlor-alkali plants were the main contributors. Estimates for PCBs were done only for the U.S. as PCBs are not reported to the NPRI. For the same time period, over 758,000 kg (1.7 million lbs) of PCBs were released, 99% of which went to onsite landfills. The top contributor was waste management companies.

Per the recommendations of the Lake Erie LaMP Habitat Strategy, a project is underway to develop a unified, consensus-based habitat classification system and an associated geospatial database that integrates classification systems at relevant scales into map layers. The goal is to create a binational GIS-based habitat map. Several workshops have been held to involve the technical experts and managers. Testing and validation is planned for the Maumee River and Grand River watersheds, after which the project will be expanded to the rest of the Lake Erie basin.

Other habitat projects underway include: an assessment of coastal wetlands around Rondeau Bay (Ontario Ministry of Natural Resources); the Fort Malden shoreline stabilization/habitat enhancement project and the McKee Park habitat enhancement project (Essex Region Conservation Authority); and the Middle Harbor fish habitat restoration project (Ohio Department of Natural Resources). The Huron-Erie Corridor system habitat assessment is creating a framework and designing a process to identify, coordinate and implement aquatic habitat restoration opportunities in the Lake Huron to Lake Erie Corridor. The Huron-Erie Corridor project is being conducted within the context of long-term water level regime changes resulting from direct hydro-modification and/or potential effects of global climate change. USGS completed the Ohio Aquatic GAP analysis project in 2005. Seventy-five (15%) of 504 14-digit hydrologic sub-watershed units in the Lake Erie basin were identified as having high potential for priority conservation. Thirty-seven of the 75 sub-watersheds already include some conservation lands within their boundaries.

From a human health perspective, as required by legislation passed stemming from the Walkerton, Ontario situation, watershed plans to protect drinking water sources are being developed in Ontario. On the U.S. side, the passage of the Beaches Environmental Assessment and Coastal Health Act (BEACH Act) in 2000 has done much to standardize criteria for beach postings, improve sampling methodology and frequency, and improve communication to the public concerning the water quality at public beaches. In 2005, 33 of the 66 beaches monitored along the U.S. shoreline had at least one day when beaches were posted.

Updates are included on the progress of 12 RAPs and seven watershed initiatives around Lake Erie. Each update provides a short history of the process and past actions, progress since the 2004 LaMP report and next steps. A matrix summarizing each area is included for the first time. These reports indicate continuing interest and participation in RAP and watershed programs. The involvement of local groups and agencies is a critical component in the success of restoring beneficial uses to these areas and to ultimately reduce impacts on the lake.

Since the late 1970s, concentrations of PCBs, DDT and mercury have generally declined in Lake Erie walleye, smelt and lake trout, although a fair degree of variability is seen from year to year. Over the sampling period, no fish have ever exceeded GLWQA criteria for DDT or mercury (1.0 µg/g and 0.5 µg/g, respectively). PCBs in walleye and lake trout consistently exceed the GLWQA of 0.1 µg/g, while rainbow smelt hover near or below the criteria.


Photo: Upper Thames River Conservation Authority

In the last decade, in-lake concentrations of phosphorus have been on the rise. Hypoxia and anoxia in the central basin are more extensive and occurring earlier in the summer, while *Microcystis* blooms and *Cladophora* growth have been observed recently to rival those of the 1970s. These signs all suggest that Lake Erie is out of trophic control once again. Lake Erie was monitored in 2004 under the U.S and Canada collaborative comprehensive survey (ECCS) with the next round planned for 2009. Sampling was focused on observing key physical and water quality measurements, nearshore/offshore exchanges and the impacts of zebra and quagga mussels. In 2005, under the International Field Year on Lake Erie (IFYLE) program, research/monitoring was done to gather information to help forecast the onset, duration and extent of hypoxia and harmful algal blooms across the basin and to assess the ecological consequences of hypoxia on the food web. While the results of these studies are still forthcoming, many hypotheses implicate zebra and quagga mussels as a major cause of the lake's current problems. Long-term tributary monitoring work conducted by the National Center for Water Quality Research at Heidelberg College suggests a trend of increasing concentrations and loads of sediments and nutrients from the monitored tributaries in Michigan and Ohio. Of particular interest is the increase in the amount of dissolved reactive phosphorus as it is the most bioavailable form of phosphorus.

In the fall of 2005, hydrogen sulfide gas was released from the hypolimnion during the fall turnover. The extent of this release ranged from Cleveland to Buffalo and was so pervasive as to be investigated by emergency response teams in Pennsylvania as a gas leak, sewage discharge or chemical explosion. However, monitoring buoys installed by NOAA under IFYLE verified that this was indeed a phenomenon associated with lake turnover. Under the appropriate weather conditions, and if anoxia continues to move closer to shore, we can anticipate seeing this situation repeat itself more frequently.

The Lake Erie LaMP process is changing from assessment to implementation. For the next two years the LaMP will be reviewing its management structure and better identifying those actions that need to be taken on a lakewide basis or at the watershed level to obtain the ecosystem objectives set by the LaMP.

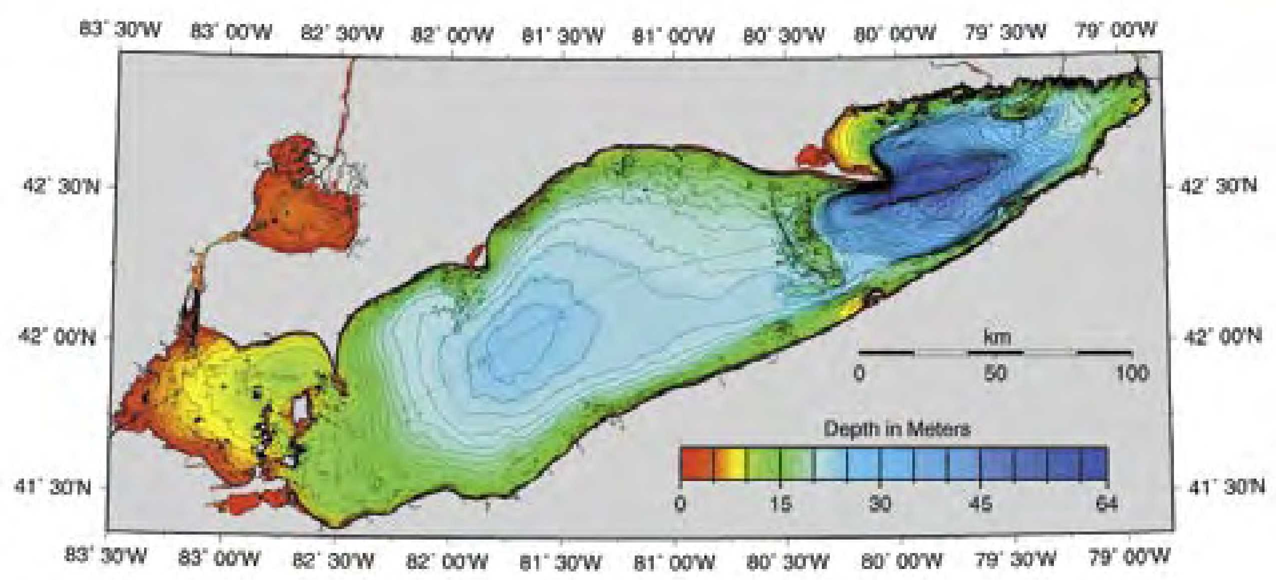
Section 2: Overview

2.1 Introduction to Lake Erie

The physical characteristics of Lake Erie have a direct bearing on how the lake ecosystem reacts to various stressors. By volume it is the smallest of the Great Lakes, and next to smallest in surface area. As the shallowest of the Great Lakes, it warms quickly in the spring and summer and cools quickly in the fall. During long, cold winters, a large percentage of Lake Erie is covered with ice, and occasionally it freezes over completely. Conversely, in warmer years, there may be no ice at all. The shallowness of the basin and the warmer temperatures make it the most biologically productive of the Great Lakes.

Lake Erie is naturally divided into three basins (Figure 2.1). The western basin is very shallow having an average depth of 7.4 metres (24 ft.) and a maximum depth of only 19 metres (62 ft.). The central basin is quite uniform in depth, with the average depth being 18.3 metres (60 ft.) and the maximum depth 25 metres (82 ft.). The eastern basin is the deepest of the three with an average depth of 25 metres (82 ft.) and a maximum depth of 64 metres (210 ft.). The central and eastern basins thermally stratify every year, but stratification in the shallow western basin is rare and very brief, if it does occur. Stratification impacts the internal dynamics of the lake, physically, biologically and chemically. These physical characteristics cause the lake to function as virtually three separate lakes.

Figure 2.1: Bathymetry of Lake Erie illustrating that the lake is comprised of three distinct basins, primarily defined by depth



Lake Erie's long narrow orientation parallels the direction of the prevailing southwest winds. Strong southwest winds and strong northeast winds set up extreme seiches, creating a difference in water depth as high as 4.3 metres (14 ft.) between Toledo and Buffalo (Hamblin, 1979). The effect is most spectacular in the western basin where large areas of the lake bottom are exposed when water is blown to the northeast, or large areas of shoreline are flooded as water is blown to the southwest. Overall current and wave patterns in Lake Erie are complex, highly changeable and often related to wind direction (Bolsenga and Herdendorf, 1993).

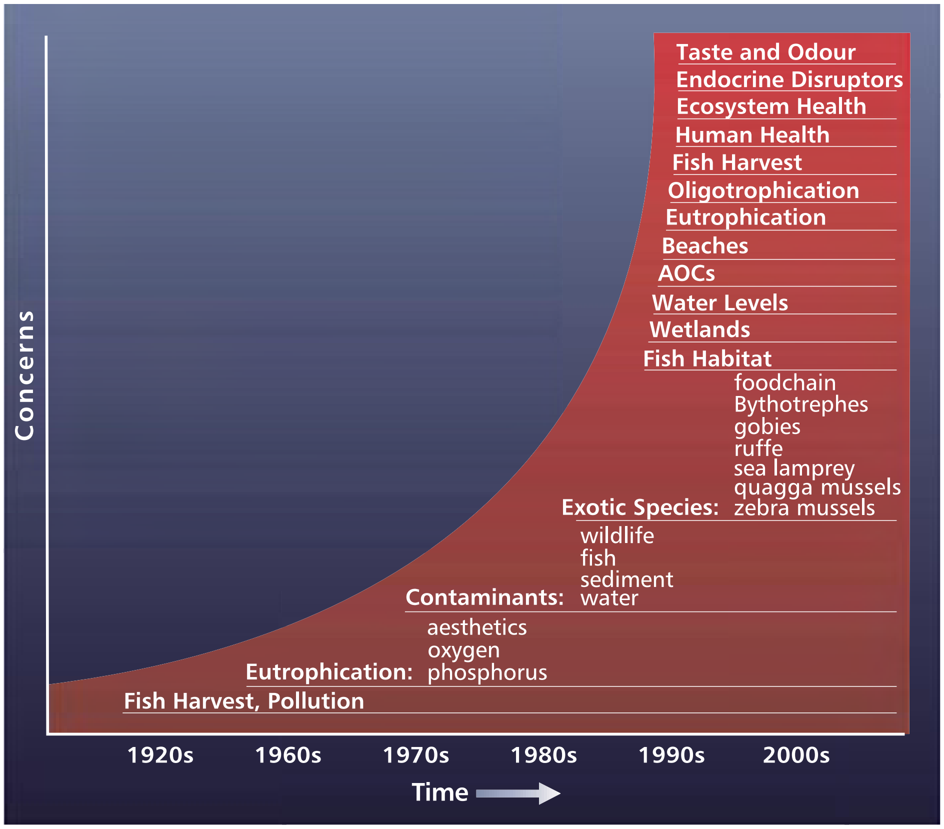
Eighty percent of Lake Erie's total inflow of water comes through the Detroit River. Eleven percent is from precipitation. The remaining nine percent comes from the other tributaries flowing directly into the lake from Michigan, Ohio, Pennsylvania, New York and Ontario (Bolsenga and Herdendorf, 1993). The Niagara River is the main outflow from the lake.

About one-third of the total population of the Great Lakes basin resides within the Lake Erie watershed. This amounts to 11.6 million people (10 million U.S. and 1.6 million Canadian), including 17 metropolitan areas, each with more than 50,000 residents. The lake provides drinking water for 11 million people.

Of all the Great Lakes, Lake Erie is exposed to the greatest stress from urbanization, industrialization and agriculture. Reflecting the fact that the Lake Erie basin supports the largest population, it surpasses all the other Great Lakes in the amount of effluent received from sewage treatment plants (Dolan, 1993). Lake Erie is also the Great Lake most subjected to sediment loading. Intensive agricultural development, particularly in southwest Ontario and northwest Ohio, contributes huge sediment loads to the lake. The Detroit River delivers sediment from the actively eroding shoreline of southeastern Lake Huron and Lake St. Clair. Long stretches of the Lake Erie shoreline experience episodes of active erosion, particularly during storms and periods of high water. The western basin is generally the most turbid region of the lake, and much of its sediment load eventually moves into the central and eastern basins. Suspended sediment can be considered a pollutant in itself, one that has profoundly influenced the ecology of the western basin and the river mouths of most of the Lake Erie tributaries. Most of the lake bottom is covered with fine sediment particles that are easily disturbed when the shallow lake is stirred up by winds.

Over the years, as use of the lake and land use around the basin changed, so too did the issues of concern in Lake Erie. The most important issues and the timeframe during which they appeared are illustrated in Figure 2.2. It is interesting to note how some of the issues recur, albeit due to different reasons. Commercial overfishing, pollution and habitat destruction began to take a toll in the late 1800s, and popular commercial fish populations plummeted. Many of the drinking water intakes for the major populated areas were moved far offshore to avoid epidemics of waterborne diseases, such as typhoid, resulting from raw sewage discharge. Nuisance conditions, floating debris, and odors were increasingly common.

Figure 2.2: Changing issues in Lake Erie over time



Lake Erie was the first of the Great Lakes to demonstrate a serious eutrophication problem. Its shallow nature made it the warmest and most biologically productive of the Great Lakes, but increased nutrient loadings beginning in the1950s made it too productive. Results of this accelerated eutrophication were unhealthy, unattractive and odiferous. Algal blooms caused thick green and blue-green slicks on the water surface; turbidity increased due to more algae and suspended sediment in the water column; and excess *Cladophora*, a long, green, filamentous algae, covered the shoreline in slimy masses and mounded up on beaches when it died. A result of this increased productivity was oxygen depletion in the bottom waters of the lake as algae died, settled to the bottom and decomposed. The central basin is particularly susceptible to oxygen depletion because summer stratification forms a relatively thin hypolimnion at the bottom that is isolated from oxygen-rich surface waters. Oxygen is rapidly depleted from this thin layer as a result of decomposition of organic matter. When dissolved oxygen levels reach <1mg/l, the waters are considered to be anoxic. In addition to stressing and/or eliminating biological communities, anoxia changes chemical processes on the bottom, regenerating phosphorus from the sediments and recycling it back into the water column.

Accelerated eutrophication spanned the 1950s to the 1970s, with much of the central basin becoming anoxic. Phosphorus was deemed to be the main culprit (Burns, 1985). A comprehensive binational phosphorus reduction strategy was implemented to reduce phosphorus discharge from wastewater treatment plants, limit the use of phosphorus-containing detergents in the watershed, and to develop and encourage the use of best management practices to reduce phosphorus runoff from agricultural operations.

Increased industrialization and the formulation of new chemicals to aid in pest control led to concern about contaminants and the accumulation of persistent toxic chemicals in water, sediment, fish and wildlife. The development of extensive pollution control regulations, improvements in treatment technologies, adoption of stringent water quality standards, bans on production and use of certain chemicals, waste minimization and pollution prevention have greatly reduced the direct discharge of contaminants. However, the lingering effects of these historic discharges, such as contaminated sediments and fish consumption advisories, and a greater public awareness of the environment raised further concerns about contaminants in the late 1970s that has continued to the present.

Photo: U.S. EPA Great Lakes National Program Office

Efforts to restore lake trout, the extirpated top-predator in the cold waters of the eastern basin, were thwarted in the late 1970s and early 1980s by mortality caused by the non-native invasive sea lamprey. Sea lamprey invaded Lake Erie and the upper Great Lakes after the Welland Canal was expanded in the early 1900s (Eshenroder and Burnham-Curtis 1999). Their abundance increased during the 1970s to the point that control efforts were implemented beginning in 1986.

The introduction of zebra mussels in the late 1980s triggered a tremendous ecological change in the lake. Zebra mussels have changed the habitat in the lake, altering the food web dynamic, energy transfer and how nutrients and contaminants are cycled within the lake ecosystem. Additional non-native invasive species such as the quagga mussel, goby, and several large zooplankton species have further complicated the system.

In the 1990s, changing fish populations fueled a whole new debate on phosphorus loading. Lake Erie had essentially achieved the phosphorus levels established under the Great Lakes Water Quality Agreement as those needed to eliminate the effects of eutrophication. However, the models used to determine the maximum allowable annual phosphorus load did not account for the influence of such a major ecosystem disruptor as the zebra mussel. Eastern basin open water phosphorus concentrations are now even less than the 10 µg/l target value, dramatically reducing the productivity of that basin. Yet, some of the nearshore areas have phosphorus concentrations high enough to support extensive *Cladophora* growth. Attempting to manage the lake system now by simply increasing or decreasing phosphorus loads is no longer workable. Until more is understood about the internal dynamics of phosphorus cycling in the lake, the Lake Erie LaMP has taken the position to continue to support implementation of phosphorus management programs to maintain the phosphorus targets established under the GLWQA.

Changes in land use, development, and the construction of various shore structures have significantly altered the original habitat available along the Lake Erie shoreline. Many of the wetlands have been drained, filled or altered so they no longer function naturally. Shore structures associated with development or built to protect shore property from high water levels have inhibited the natural flow of beach building materials along the shoreline, and, consequently, the natural habitat.

The potential impact of endocrine disruptors on the aquatic community and human health is another issue of concern raised in the 1990s. Weight of evidence suggests that known endocrine disruptor contaminants, such as PCBs, may be impairing Lake Erie populations, both aquatic and human, but it is difficult to make the cause and effect connections.

Issues of concern in Lake Erie will continue to fluctuate over time. Most recently, the area of anoxia in the central basin has expanded, even with the lower phosphorus concentrations in the lake. A number of research projects are ongoing to investigate the cause and the potential impacts.

Current surveillance and monitoring information and recent research must be available to make the appropriate management decisions to address new issues as they arise. Management decisions and actions should take into consideration the potential impact on the overall ecosystem. Using the structure provided by the Lake Erie LaMP process, future remedial and management actions concerning the lake will take into account the expertise, goals and combined resources of the interested public, the private sector, researchers and all the agencies with some jurisdiction over the lake.

2.2 LaMP Structure and Process

Under the Great Lakes Water Quality Agreement (GLWQA) of 1978, as amended by Protocol in 1987, the United States and Canada (the Parties) agreed, "…to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem."

To achieve this goal, the Parties agreed to develop and implement Lakewide Management Plans (LaMPs) for each lake, in consultation with state and provincial governments. The 14 beneficial use impairments listed in Annex 2 of the GLWQA (Table 2.1) are a main focus of LaMPs.

The GLWQA calls for LaMPs specifically to address persistent bioaccumulative toxic substances, particularly those that are causing or likely to cause beneficial use impairments. Ecosystem objectives specific to each lake are to be established to guide LaMP efforts toward defined endpoints. Based on achieving these ecosystem objectives, the LaMPs provide a binational structure for addressing environmental and natural resource issues, coordinating research, pooling resources and making joint commitments to improve the environmental quality of the lakes.

In 1993, a temporary binational Implementation Committee was formed, consisting of members of all the state, federal and provincial agencies with jurisdiction over Lake Erie. The charge to this group was to create a framework upon which to build the Lake Erie LaMP.

Table 2.1: IJC Listing Criteria for Establishing Impairment (IJC, 1989)

Beneficial Use Impairment	IJC Listing Criteria
Restrictions on Fish and Wildlife Consumption	When contaminant levels in fish or wildlife populations exceed current standards, objectives or guidelines, or public health advisories are in effect for human consumption of fish and wildlife.
Tainting of Fish and Wildlife Flavor	When ambient water quality standards, objectives, or guidelines for the anthropogenic substance(s) known to cause tainting are being exceeded or survey results have identified tainting of fish and wildlife flavor.
Degraded Fish and Wildlife Populations	When fish or wildlife management programs have identified degraded fish or wildlife populations. In addition, this use will be considered impaired when relevant, field validated, fish and wildlife bioassays with appropriate quality assurance/quality controls confirm significant toxicity from water column or sediment contaminants.
Fish Tumors and Other Deformities	When the incidence rates of fish tumors or other deformities exceed rates at un-impacted control sites or when survey data confirm the presence of neoplastic or pre-neoplastic liver tumors in bullheads or suckers.
Bird and Animal Deformities or Reproductive Problems	When wildlife survey data confirm the presence of deformities (e.g. cross-bill syndrome) or other reproductive problems (e.g. eggshell thinning) in sentinel wildlife species.
Degradation of Benthos	When the benthic macroinvertebrate community structure significantly diverges from un-impacted control sites of comparable physical and chemical characteristics. In addition, this use will be considered impaired when toxicity (as defined by relevant, field validated bioassays with appropriate quality assurance/quality controls) of sediment associated contaminants at a site is significantly higher than controls.
Restrictions on Dredging Activities	When contaminants in sediments exceed standards, criteria, or guidelines such that there are restrictions on dredging or disposal activities.
Eutrophication or Undesirable Algae	When there are persistent water quality problems (e.g. dissolved oxygen depletion of bottom waters, nuisance algal blooms or accumulation, decreased water clarity, etc.) attributed to cultural eutrophication.
Restrictions on Drinking Water Consumption or Taste and Odor Problems	When treated drinking water supplies are impacted to the extent that:1) Density of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances exceed human health standards, objectives or guidelines; 2) Taste and odor problems are present; or 3) Treatment needed to make raw water suitable for drinking is beyond the standard treatment used in comparable portions of the Great Lakes which are not degraded (i.e. settling, coagulation, disinfection).
Recreational Water Quality Impairments	When waters, which are commonly used for total-body contact or partial-body contact recreation, exceed standards, objectives, or guidelines for such use.
Degradation of Aesthetics	When any substance in water produces a persistent objectionable deposit, unnatural color or turbidity, or unnatural odor (e.g. oil slick, surface scum).
Added Costs to Agriculture or Industry	When there are additional costs required to treat the water prior to use for agricultural purposes (i.e. including, but not limited to, livestock watering, irrigation and crop spraying) or industrial purposes (i.e. intended for commercial or industrial applications and noncontact food processing).
Degradation of Phyto/ Zooplankton Populations	When phytoplankton or zooplankton community structure significantly diverges from un-impacted control sites of comparable physical and chemical characteristics. In addition, this use will be considered impaired when relevant, field-validated, phytoplankton or zooplankton bioassays (e.g. *Ceriodaphnia*; algal fractionation bioassays) with appropriate quality assurance quality controls confirm toxicity in ambient waters.
Loss of Fish and Wildlife Habitat	When fish or wildlife management goals have not been met as a result of loss of fish or wildlife habitat due to a perturbation in the physical, chemical or biological integrity of the Boundary Waters, including wetlands.

This committee produced the Lake Erie LaMP Concept Paper (U.S. EPA 1995). In addition to addressing critical pollutants, the Implementation Committee felt the integrity of the Lake Erie ecosystem would not be fully protected or restored unless other factors such as habitat loss, nutrient and sediment loading, and non-native invasive species were addressed as well. Therefore, they recommended the scope of the LaMP be broadened to include these other environmental stressors. This decision directed the agencies to embody a stronger overall ecosystem approach in the development of the LaMP. In 1995, binational committees were established to begin actively working on the development of the Lake Erie LaMP. A Status Report was completed in 1999 (U.S. EPA and Environment Canada 1999).

In order to explain clearly the geographic scope of the Lake Erie LaMP, three aspects need to be defined. First, beneficial use impairments were assessed within the waters of Lake Erie, including: the open waters, nearshore areas, and river mouth/lake effect areas. Second, the search for the sources or causes of impairments to beneficial uses is being conducted in the lake itself, the Lake Erie watershed, and even beyond the Great Lakes basin. Third, management actions needed to restore and protect Lake Erie may need to be defined and implemented outside of the Lake Erie basin.

Environment Canada and the U.S. Environmental Protection Agency are the federal co-leads for the Lake Erie LaMP. Other agencies involved in the process include:

Canada
- Agriculture and Agri-food Canada (invited)
- Department of Fisheries and Oceans
- FOCALerie (Federation of Conservation Authorities of Lake Erie)
- Health Canada
- Ontario Ministry of Agriculture and Food
- Ontario Ministry of the Environment
- Ontario Ministry of Natural Resources

United States
- Agency for Toxic Substances and Disease Registry
- Michigan Department of Environmental Quality
- Michigan Department of Natural Resources
- Natural Resource Conservation Service
- New York State Department of Environmental Conservation
- Ohio Department of Natural Resources
- Ohio Environmental Protection Agency
- Pennsylvania Department of Environmental Protection
- Seneca Nation of Indians (invited)
- US Army Corps of Engineers (invited)
- US Fish and Wildlife Service
- US Geological Survey

Binational Observers
- International Joint Commission
- Great Lakes Fishery Commission

Senior managers from each jurisdiction were invited to participate on the Lake Erie LaMP Management Committee, the group charged with overseeing the development of the Lake Erie LaMP. A number of committees and subcommittees were established to assist the Management Committee in fulfilling its charge. The primary supporting committee under the Management Committee is the Lake Erie Work Group. The Work Group carries out the directives of the Management Committee and oversees the creation and progress of the various subcommittees. The Work Group prepares or oversees all the documents prepared under the LaMP and presents them to the Management Committee for review and approval.

Per the direction of the GLWQA, the Lake Erie Concept Paper proposed significant public involvement be utilized throughout the LaMP process. The Lake Erie Binational

Photo: Lower Thames Valley Conservation Authority

Public Forum was created to provide front line coordination and communication with the interested public, and to initiate additional public activities. The Forum contributed to and reviewed the technical background documents used to prepare the LaMP as well as implemented a number of public outreach and education projects in support of the LaMP. The original organizational structure of the Lake Erie LaMP is presented in Figure 2.3.

As the LaMP moved from development to more of an implementation stage, the LaMP structure changed. The current structure is depicted in Figure 2.4. The LaMP has established a research connection via association with the Lake Erie Millennium Network (LEMN). The LEMN was co-convened by the Great Lakes Institute for Environmental Research at the University of Windsor, U.S. EPA's Large Lakes Research Station, the National Water Research Institute of Environment Canada, and Ohio Sea Grant-F.T. Stone Laboratory of the Ohio State University. The LEMN hosts a biennial conference on the status of Lake Erie and identifies current research needs, and works with the LaMP to organize workshops to address various research needs and data gaps.

In an effort to accelerate the entire Great Lakes LaMP process, the Binational Executive Committee (BEC) issued a resolution in July 1999 that recommended a change from the four-stage LaMP process, described in the GLWQA, to production of a biennial document on LaMP status (Table 2.2). This allows planning and implementation to occur simultaneously rather than sequentially, and puts more emphasis on implementation than on document production and review. Having comparable documents for all of the lakes will help to set priorities and identify the issues that may need to be addressed on a Great Lakes basinwide scale.

Figure 2.3: Original organizational structure of the Lake Erie LaMP

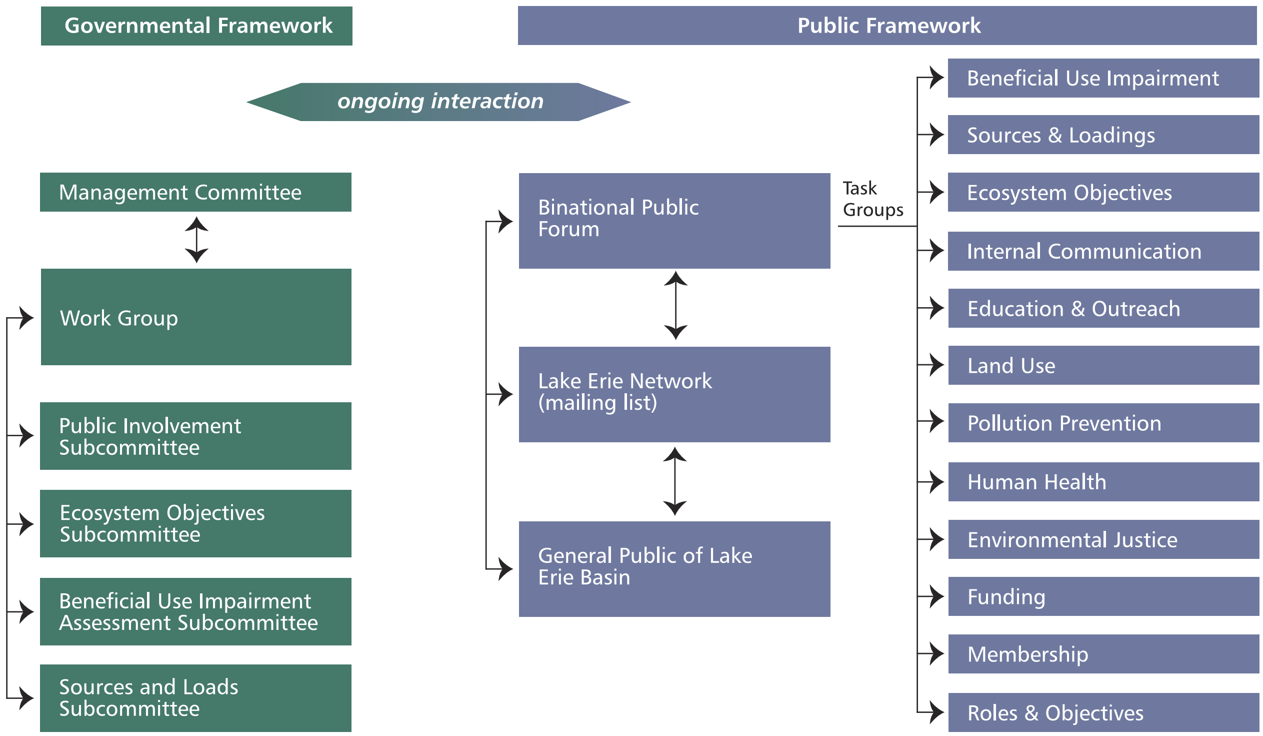


Figure 2.4: Current LaMP organizational structure

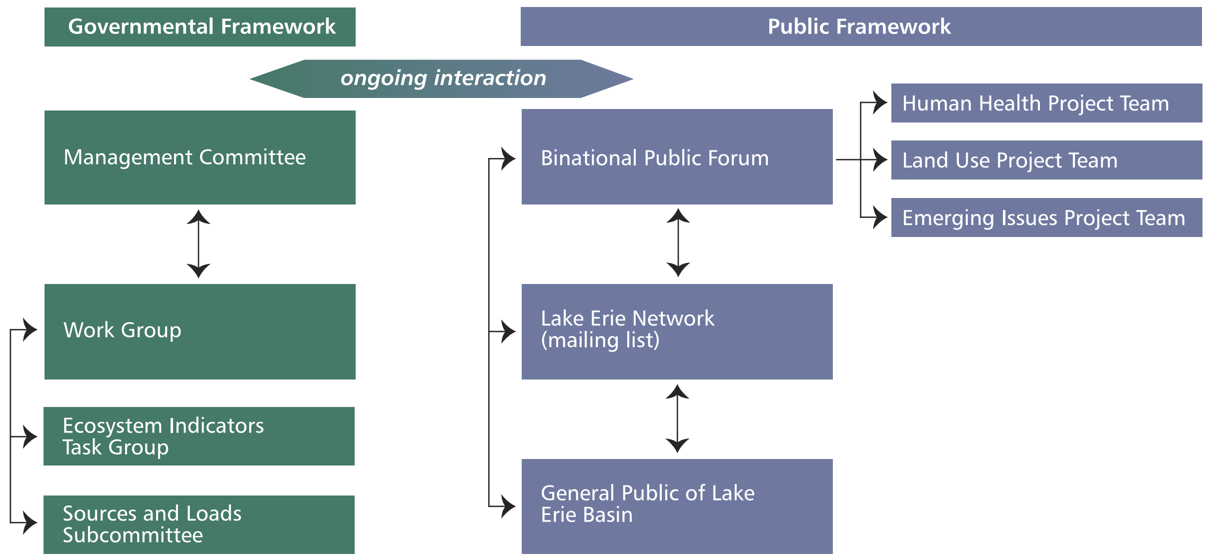


Table 2.2: Binational Executive Committee Consensus Position on the Role of LaMPs in the Great Lakes Restoration Process

The development and implementation of Lakewide Management Plans (LaMPs) are an essential element of the process to restore and maintain the chemical, physical, and biological integrity of the Great Lakes ecosystem. Through the LaMP process, the Parties, with extensive stakeholder involvement, have been defining the problems, finding solutions, and implementing actions on the Great Lakes for almost a decade. The process has taken much longer and has been more resource-intensive than expected.

In the interest of advancing the rehabilitation of the Great Lakes, the Binational Executive Committee calls on the Parties, States, Provinces, Tribes, First Nations, municipal governments, and the involved public to significantly accelerate the LaMP process. By accelerate, we mean an emphasis on taking action and a streamlined LaMP review and approval process. Each LaMP should include appropriate actions for restoration and protection to bring about actual improvement in the Great Lakes ecosystem. Actions should include commitments by the governments, parties and regulatory programs, as well as suggested and voluntary actions that could be taken by non-governmental partners. BEC endorses the April 2000 date for the publication of "LaMP 2000," with updates every two years.

BEC is committed to ensuring a timely review process and will be vigilant in its oversight.

The BEC respects and supports the role of each Lake Management Committee in determining the actions that can be achieved under each LaMP. BEC expects each Management Committee to reach consensus on those implementation and future actions. Where differences cannot be resolved, BEC is committed to facilitating a decision. BEC recognizes the Four-Party Agreement for Lake Ontario and the uniqueness of the agreed upon binational workplan.

The LaMPs should treat problem identification, selection of remedial and regulatory measures, and implementation as a concurrent, integrated process rather than a sequential one. The LaMPs should embody an ecosystem approach, recognizing the interconnectedness of critical pollutants and the ecosystem. BEC endorses application of the concept of adaptive management to the LaMP process. By that, we adapt an iterative process with periodic refining of the LaMPs which build upon the lessons, successes, information, and public input generated pursuant to previous versions. LaMPs will adjust over time to address the most pertinent issues facing the Lake ecosystems. Each LaMP should be based on the current body of knowledge and should clearly state what we can do based on current data and information. The LaMPs should identify gaps that still exist with respect to research and information and actions to close those gaps.

Adopted by BEC on July 22, 1999.

2.3 References

Bolsenga, S.J., and C.E. Herdendorf [Eds]. 1993. Lake Erie and Lake St. Clair Handbook. Wayne State University Press, Detroit, Michigan.

Burns, N.M. 1985. Erie, The Lake That Survived. Rowman & Allanheld, Publishers, Totowa, New Jersey.

Cornelius, F.C., K.M. Muth, and R. Kenyon. 1995. Lake trout rehabilitation in Lake Erie: a case history. J. Great Lakes Res. 21(Supplement 1):65-82.

Dolan, D.M. 1993. Point Source Loading of Phosphorus to Lake Erie. J. Great Lakes Res. 19:212-223.

Eshenroder,R.E., M.K. Burnham-Curtis. 1999. Species succession and sustainability of the Great Lakes fish community. *In* Great Lakes Fisheries Policy and Management, a Binational Perspective. W.W. Taylor and C.P. Ferreri eds. Michigan State University Press. Pp. 145-184

Hamblin, P.F. 1979. Great Lakes storm surge of April 6, 1979. J. Great Lakes Res. 5:312-315.

International Joint Commission. 1989. Proposed listing/delisting criteria for Great Lakes Areas of Concern. In: Focus on International Joint Commission Activities. Vol.14(1): insert.

U.S. EPA. 1995. Lake Erie LaMP Concept Paper.

U.S. EPA and Environment Canada. 1999. Lake Erie LaMP Status Report.

Section 3: Vision, Ecosystem Management Objectives, and Indicators

3.1 Introduction

The Lake Erie LaMP has adopted a generalized ecosystem approach, as outlined in the 1987 amendments to the Great Lakes Water Quality Agreement (GLWQA). This approach recognizes that all components of the ecosystem are interdependent, including the water, biota, surrounding watershed and atmosphere. Humans are considered an integral part of the system. The GLWQA calls for the development of ecosystem objectives and indicators for all the Great Lakes. These would be used to facilitate effective management and co-ordination within and between agencies working in the Lake Erie watershed. There are three steps involved in setting a direction for the Lake Erie ecosystem: 1) a preferred ecosystem management alternative must be selected; 2) ecosystem vision and management objectives must be developed that describe in narrative form more details to set the stage for the actions needed to achieve the preferred alternative; and 3) indicators must be developed to measure progress in achieving the desired ecosystem alternative.

3.2 Selection of a Lake Erie Ecosystem Management Alternative

Ecosystem Alternative Development Process

For Lake Erie, the level of change in the ecosystem has been extensive, and in many cases appears irreversible (Burns 1985). We cannot return to the pre-settlement conditions of the 1700s, but we can work toward achieving a healthier, more diverse and less contaminated ecosystem.

The Lake Erie LaMP Ecosystem Objectives Subcommittee (EOSC) was charged with the task of developing ecosystem management objectives for Lake Erie. The EOSC is a binational group of about 15 individuals with expertise in limnology, water quality, and fisheries and wildlife management. Three members of the Lake Erie Binational Public Forum worked closely with the committee throughout the exercise. The first step in the process was to identify ecosystem management alternatives. The committee began the exercise by holding four public workshops around the basin to gain ideas on the desired state of the Lake Erie ecosystem. This was followed by an expert workshop where published information and expert opinion were solicited concerning key relationships in the ecosystem.

A conceptual model of three ecosystem alternatives was developed for initial discussion. Several other attempts were made at developing a model that could be used for Lake Erie. As a result, a fuzzy cognitive map (FCM) approach was adopted to model ecosystem alternatives for Lake Erie. A FCM model is one way to analyze a complex system by representing the most important components of the system as nodes of a network. A change at one node will affect all connected nodes, and then all the nodes connected to those nodes, generating a ripple effect. Taking an FCM approach required more data and, therefore, a second expert workshop was held. The results of the second workshop led to the development of an FCM model for the lake dubbed the Lake Erie Systems Model. The model is being used as a tool to help understand how various components of the ecosystem interact, but it is not a panacea to predict future conditions.


Photo: Michelle Fletcher

Three major categories of actions and reactions are used to explain the output of the Lake Erie Systems Model: 1) management levers; 2) ecosystem health response; and 3) beneficial use to humans. Management levers are a variety of human actions that affect the ecosystem. Ecosystem health response describes the condition of individual biotic and habitat components and the reaction to the management levers. Beneficial uses refer to those uses defined in the GLWQA that are affected by the management levers. By randomly and simultaneously moving all management levers in different directions and monitoring responses of all non-lever variables, a large set of different potential outcomes in the ecosystem can be generated. These outcomes can then be grouped into a form that can be recognized and described using a statistical clustering procedure. Groups that are considered to be significantly different from each other constitute ecosystem alternatives. A detailed description of how the model was developed and how it processes data can be found in the ecosystem objectives subcommittee's report, Colavecchia et al. (2000).

The model generated various ecosystem alternatives. These alternatives do not include social, economic, or political values because they are not part of the natural ecosystem. Rather, these values were used to determine the ecosystem alternative that was chosen.

Model Results

Of the management levers examined in the model, those that affected the availability of natural, undisturbed land caused the largest response across the greatest number of variables. Therefore, the availability of natural lands was the key driver of the ecosystem clusters. Nutrient levels were the second most important influence but did not have the impact that natural land (habitat) had on the ecosystem. In other words, phosphorus can be strictly managed, but unless natural land or habitat is protected and restored, only marginal response will be seen by many components of the ecosystem. It was determined that changes in land use that represent a return towards more natural landforms or that mitigate the impacts of urban, industrial and agricultural land use, are the most significant actions that can be taken to restore the Lake Erie ecosystem.

The ecosystem alternatives derived from the model were described based on their gain in natural land compared to the status quo conditions of the 1990s. From the modeling exercise, seven distinct ecosystem management alternatives emerged. Three alternatives represented highly degraded environmental conditions relative to 1990 conditions and were discarded as not viable alternatives for a future state of Lake Erie. The remaining four alternatives (Table 3.1) represented existing or improved environmental conditions. Alternative 3 represents moderate loss of natural landforms relative to status quo (Alternative

Table 3.1: Summary of Ecosystem Alternatives for Lake Erie

Management Lever or *effect*	Action or ***effect***	**Ecosystem Alternatives**			
		1	2	3	4
Agricultural Land Use	Mitigation of impact	very strong	strong	strong	status quo
Industrial Land Use	Mitigation of impact	very strong	moderate	moderate	status quo
Urban Land Use	Mitigation of impact	very strong	strong	moderate	status quo
Natural Landscapes	Restoration	small gain	small gain	moderate loss	status quo
Phosphorus Concentration	Reduced concentrations in tributaries, nearshore and lake	very strong	strong	strong	status quo
Phosphorus from Land (non-point source)	Reduction in loadings	very strong	very strong	very strong	status quo
Phosphorus from STPs	Reduction in loadings	very strong	moderate	strong	status quo
Total Suspended Solids	Reduction in concentration	very strong	very strong	very strong	status quo

4), while Alternatives 1 and 2 represent small improvements in the amount of natural landscapes in the basin. Alternatives 3, 2, and 1 represent increasingly more progressive mitigation of agricultural, industrial and urban land uses. The mitigation results in very strong reductions in nutrient export from land and total suspended solids concentrations. The alternatives differ in the level of reduction of phosphorus exports from sewage treatment plants (STPs) with Alternative 2 requiring moderate reduction, Alternative 3 a strong reduction and Alternative 1 a very strong reduction.

The selection of an ecosystem alternative toward which to manage Lake Erie is not a trivial issue. There are many competing and incompatible uses of Lake Erie, and multiple agencies (federal, state and local) have jurisdiction over one or more components of the ecosystem. Societal factors that influence the choice include economics, social justice, land use, and others. To be an effective tool, the LaMP, including the desired ecological state for Lake Erie, must have the support and commitment of the various environmental managers, decision makers and the public. Without a consensus on ecological conditions to be achieved, multiple management efforts could easily be competing, ineffective, and/or counterproductive. Ultimately, the process for choosing an ecosystem alternative for management purposes becomes one of identifying which one is most closely compatible with societal values of the residents in the basin.

The Lake Erie LaMP Work Group considered several options for soliciting opinions and comments on preferred ecosystem alternatives from the governing agencies, environmental groups, industry and the general public. Opinions were solicited through informal discussions, Lake Erie Binational Public Forum input, and agency reviews. In June 2000, the LaMP Work Group reached consensus that Ecosystem Alternative 2 would represent the preferred ecosystem of the Work Group. In September 2001, the LaMP Management Committee endorsed this conclusion. Additional discussions with stakeholders, including the public, concluded with the selection of Ecosystem Alternative 2.

Ecosystem Alternative 2 is consistent with the themes of sustainable development and of multiple benefits to society of a healthy Lake Erie ecosystem. The analysis supporting Ecosystem Alternative 2 highlights the importance and urgency of improving land use activities, continued diligence in nutrient management, and the vulnerability of fish and wildlife species to human activities.

3.3 Developing a Lake Erie Vision and Ecosystem Management Objectives

The second step involved in setting a direction for the Lake Erie ecosystem was the development of a vision and ecosystem management objectives using the selected ecosystem alternative. The vision is a written description of the selected ecosystem alternative. The ecosystem management objectives describe in narrative form more details to set the stage for the actions needed to achieve the Vision.

The Lake Erie LaMP has defined the term integrity, from Karr and Dudley (1981), as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitats of the region."

3.3.1 The Lake Erie Vision

Ecosystem Alternative 2 became the Lake Erie Vision. This vision is consistent with the themes of sustainability and of the multiple benefits to society of a healthy Lake Erie ecosystem. Maintaining healthy ecosystems and restoring degraded ecosystems will foster improved economic and human health through a variety of avenues (maintaining water quality, tourism, recreation, etc.). The Lake Erie Vision is presented below:

Our Vision is a Lake Erie basin ecosystem...

Where all people, recognizing the fundamental links among the health of the ecosystem, their individual actions, and their economic and physical well-being, work to minimize the human impact in the Lake Erie basin and beyond;

Where natural resources are protected from known, preventable threats;

Where native biodiversity and the health and function of natural communities are protected and restored to the greatest extent that is feasible;

Where natural resources are managed to ensure that the integrity of existing communities is maintained or improved;

Where human-modified landscapes provide functions that approximate natural ecosystem processes;

Where land and water are managed such that water flow regimes and the associated amount of materials transported mimic natural cycles; and

Where environmental health continually improves due to virtual elimination of toxic contaminants and remedial actions at formerly degraded and/or contaminated sites.

3.3.2 Developing Ecosystem Management Objectives and Rationale

Ecosystem management objectives are targets that, when all are achieved, should result in the attainment of the Vision for the Lake Erie ecosystem.

As outlined above, the Lake Erie Vision was selected after extensive review and input. However, the vision does not prescribe the necessary management goals to realize the desired ecosystem vision. Management goals are dependent on the ecosystem management objectives, formulated to be consistent with the vision, and are based on the present state of the ecosystem components. Input from the Lake Erie community on the preferred ecosystem alternative helped define the degree of implementation that will be necessary and acceptable to be consistent with the vision.

The Lake Erie ecosystem has three very distinct basins, and within the entire watershed of the lake there are 34 third-order sub-watersheds, many of which have unique features and pressures. The impact of non-native invasive species in the Lake Erie ecosystem contributes to instability, and new species continue to enter, thereby compounding the problem. Implementation of the management strategies moves the ecosystem in the right direction, and leads to improvements in biological integrity. The process is iterative. Tracking of recovery in relation to management interventions leads to projections of reasonable and feasible endpoints for biological integrity at appropriate units of the ecosystem (i.e. watersheds and areas of influence in the lake, bays, basins).

The overall proposed ecosystem management objectives are presented as principles for management actions to achieve the Lake Erie ecosystem vision. The ecosystem management objectives are presented in relation to the main management categories influencing the status of the lake: land use; nutrients; natural resource use and disturbance; chemical and biological contaminants; and non-native invasive species. In proposing these ecosystem management objectives, it is recognized that each watershed and basin may require varying degrees of implementation. The *status quo* or "current conditions" are generally reflective of conditions found in the mid-to-late 1990s.

3.3.3 Ecosystem Management Objectives and Rationale

Land Use

Strategic Objective:

Land-based activities enhance native biodiversity and ecosystem integrity.

Tactical Objective:

Land use activities result in gains in the quantity and quality of natural habitat in order to support the maximum amount of native biodiversity and community integrity that can be achieved and be sustained for the benefit of future generations.

Rationale:

Ecosystem alternative analysis identified land use practices as the dominant management category affecting the Lake Erie ecosystem. Poor land use management has resulted in increased water runoff containing sediments, nutrients, and chemicals to Lake Erie, and reduced areas of natural landscapes and habitats. Key elements within the land use management category are gains in quality natural lands and environmentally sound management practices for rural, urban and industrial landscapes.

Best management practices (BMPs) can mitigate many deleterious land uses and their impacts to the extent that natural habitat (ecosystem) quality and quantity can improve. It is expected that there will be increasing demands and pressures for land conversion in the Lake Erie basin. Proactive planning for these pressures needs to include the protection of critical habitat corridors that connect and link habitats between the lake, the wetlands and the upland habitat. Specific targets need to be established, which include securing, protecting and restoring natural lands. A watershed approach is critical to developing local solutions and to maximize gains with partners.

Nutrients

Strategic Objective:

Nutrient levels are consistent with ecosystem goals (watershed and basinwide).

Tactical Objective:

Nutrient inputs from both point and non-point sources are managed to ensure that ambient concentrations are within bounds of sustainable watershed management and consistent with the Lake Erie Vision.

Rationale:

Current nutrient inputs are resulting in reduced use of beaches, changes in aquatic community structure, and increased algal blooms. It is important that all sources that contribute to the watershed nutrient load and ultimately to the basin load, be managed to limit local and regional impacts. Best management practices and point source controls need to be implemented with consideration of the ecological requirements for the maintenance or recovery of healthy aquatic communities in the watershed, the hydrologic cycle and water usage. In addition to phosphorus, other nutrients and their various forms, such as nitrates, also need to be included in assessments of watershed and basinwide impacts.

Natural Resource Use and Disturbance

Strategic Objective:

Ecologically wise and sustainable use of natural resources

Tactical Objective:

Natural resource use (e.g. commercial and sport fishing, hunting, trapping, logging, water withdrawal) and disturbance by human presence or activity be managed to ensure that the integrity of existing healthy ecological communities be maintained and/or improved, and provide benefits to consumers.

Rationale:

Commercial and sport fishing, hunting, trapping, logging, water withdrawal and disturbance by human presence or activity may have negative impacts on target species, habitats and more broadly on other components of the ecosystem if not properly managed. Natural resource use (exploitation and disturbance) should be managed in such a manner as to encourage the recovery of degraded communities. The harvest of valued fish, timber resources, extraction of aggregate deposits, the removal of water, and the utilization of other features of the working landscape should be done in a manner that is sustainable and which affords the greatest opportunity to preserve and enhance the biological integrity of the Lake Erie ecosystem. Integrity is a general term for the recurring structure and composition of a community over time, due to internal regulation.

Sustainable management of natural resources can realize valued harvests for present and future generations and still maintain essential habitat function. Resource extraction is recognized as valued economic activity but should be done in a manner to prevent or mitigate to the greatest extent possible the negative environmental impacts.

Photo: U.S. EPA Great Lakes National Program Office

Chemical and Biological Contaminants

Strategic Objective:

Virtual elimination of toxic chemicals and biological contaminants.

Tactical Objective:

Toxic chemical and biological contaminant concentrations within the basin must be virtually eliminated.

Rationale:

Biological contaminants are defined here as pathogens, toxins released by cyanobacteria (such as microcystin from *Microcystis*) or bacteria. Toxic chemicals and biological contaminants degrade watersheds, not only impacting local fauna, but potentially having lakewide impacts. Locally contaminated areas may affect populations of fish and wildlife in the open waters of the lake if those locations are used for feeding, spawning or nursery habitat. The amount of toxic contaminants in the Lake Erie ecosystem is the result of the combined inputs from point and non-point sources within the basin, upstream loadings transported via the Detroit River, and long-range atmospheric transport from regional and global sources. Effective management of local point and non-point sources and adopting pollution prevention practices can improve, and have improved, watershed and basin ecosystem quality. However, broad based actions such as those promoted in the Great Lakes Binational Toxics Strategy, the Stockholm Convention on Persistent Organic Pollutants (POPs), and the United Nations Agenda 21 that address global atmospheric pollutant transport, are also required to fully reach this objective since these programs address regional and global atmospheric pollutant transport.

Non-native Invasive Species

Strategic Objective:

Prevent further invasions of non-native invasive species. Control existing invasive non-native species where possible.

Tactical Objective:

Non-native invasive species should be prevented from colonizing the Lake Erie ecosystem. Existing non-native invasive species should be controlled and reduced where feasible and consistent with other objectives.

Rationale:

Successful invaders may prey upon native species or compete with them for limited resources, altering the structure of the local and lakewide ecosystems. The presence of non-native invasive species is the result of intentional or unintentional introductions, or range expansion and colonization. The LaMP has identified invasive non-native species as one of the key problems impairing the Lake Erie ecosystem. The impact of non-native invasive species needs to be minimized where feasible by preventing access, and by controlling or managing them once they have entered the ecosystem.

3.4 Linking the Vision and Ecosystem Management Objectives to Beneficial Use Impairments

Restoring impaired beneficial uses to the Lake Erie watershed is a driving force behind the development of the Lake Erie LaMP. Therefore, as the LaMP developed its vision and ecosystem management objectives the relationship between these and the identified beneficial use impairments (BUIs) were defined (Colavecchia et al. 2000).

The underlying causes of the BUIs, as identified by the Beneficial Use Impairment Assessment process, are complicated. Their restoration will frequently be linked to more than one ecosystem management objective. Successful achievement of the Lake Erie LaMP vision and ecosystem management objectives will realize the restoration of beneficial use impairments. These relationships are summarized in Table 3.2.

Table 3.2: Linking Ecosystem Management Objectives to Lake Erie's Beneficial Use Impairments (Colavecchia *et al.* 2000)

Ecosystem Management Objective	Beneficial Use Impairment
Land Use	Degraded Fish and Wildlife Populations Restrictions on Fish and Wildlife Consumption Bird or Animal Deformities or Reproductive Problems Restrictions on Dredging Degradation of Benthos Eutrophication or Undesirable Algae Beach Closings Loss of Fish and Wildlife Habitat
Nutrients	Degraded Fish and Wildlife Populations Degradation of Benthos Eutrophication or Undesirable Algae Degradation of Aesthetics Degradation of Phytoplankton and Zooplankton Populations
Chemical and Biological Contaminants	Restrictions on Fish and Wildlife Consumption Bird or Animal Deformities or Reproductive Problems Fish Tumors and Other Deformities Degraded Fish and Wildlife Populations Restrictions on Dredging Activities (quality) Beach Closings Degradation of Benthos
Natural Resource Use and Disturbance	Degraded Fish and Wildlife Populations Loss of Fish and Wildlife Habitat
Non-native Invasive Species	Degraded Fish and Wildlife Populations Degradation of Benthos Degradation of Aesthetics Loss of Fish and Wildlife Habitat Eutrophication or Undesirable Algae Degradation of Phytoplankton and Zooplankton Populations

3.5 Developing Lake Erie Indicators

Ecosystem indicators and corresponding monitoring programs allow us to evaluate progress in achieving the ecosystem management objectives and the Lake Erie LaMP vision. There are many challenges associated with establishing a suite of indicators for Lake Erie because of its many unique characteristics (e.g., three distinct basins, high biodiversity, heavily populated and developed land base, vulnerability to non-native species invasions).

An Indicators Task Group was appointed by the Lake Erie LaMP Work Group and tasked with developing a suite of indicators that will allow progress toward achieving the ecosystem management objectives to be tracked. The approach being taken is to: (a) compile a list of potential indicators representative of a variety of ecosystem components; (b) complete a review of the proposed indicators; (c) get scientific consensus for the use of these indicators, and (d) present a recommended suite of indicators to the Lake Erie LaMP.

3.5.1 Purpose and Criteria for Selection

Ecosystem indicators have been identified by SOLEC (Bertram and Stadler-Salt, 1998) as measurable features that provide managerially and scientifically useful evidence of environmental and ecosystem quality, or reliable evidence of trends in quality. For Lake Erie, this definition of indicators must be broadened in order to link them to the Lake Erie Ecosystem Management Objectives. Therefore, the Lake Erie LaMP definition of an indicator is:

A measurable feature that identifies the current state of the ecosystem relative to the desired state of the ecosystem, as described by the Lake Erie Vision and Ecosystem Management Objectives.

The purpose of the Lake Erie LaMP indicator suite is to: (1) assess overall ecosystem management integrity; (2) evaluate components contributing to change at component level and basin level; (3) evaluate important components for reporting and long-term trends; and (4) provide predictive capacity (i.e., allow us to anticipate problems and adopt a proactive approach).

Numerous indicators have already been developed or are being developed to address different purposes in the Great Lakes basin and beyond. In order to ensure that the selected indicators meet the purposes of the Lake Erie LaMP, a set of selection criteria was developed. Each potential indicator will be evaluated using the selection criteria.

3.5.2 Developing Recommended Indicators

The Indicators Task Group began accumulating potential indicators using a questionnaire that was distributed to the scientific and management community in June 2004. The questionnaire requested information on indicators that were currently in use or in development, with the intent that, wherever possible, the LaMP indicator suite would build upon work that has already been done.

An indicator matrix was developed as a means of organizing and understanding the application of the proposed indicators (Table 3.3). The matrix structure is based on the five habitat zones developed by the Lake Erie Millennium Network: terrestrial, streams, coastal wetlands, nearshore, and offshore. For each indicator category, indicators will

Table 3.3: The Lake Erie Indicators Matrix

Indicator Category	Habitat Zone				
	Terrestrial	Streams	Coastal Wetlands	Nearshore	Offshore
PRESSURE INDICATORS					
Management Objectives:					
Natural Lands					
Nutrients					
Chemical Contamination					
Biological Contamination					
Non-Native Invasive Species					
Resource Use and Disturbance					
Processes:					
Flow Disruption					
Energy Disruption					
Economic Disruption					
STATE INDICATORS					
Plant Cover					
Food Web Base					
Lower Food Web (benthic invertebrates)					
Lower Food Web (plankton)					
Middle Food Web (fish)					
Upper Food Web (fish)					
Upper Food Web (amphibians/reptiles/ birds)					

be developed within each habitat zone. The matrix is divided into two general indicator categories utilized by SOLEC: pressure and state (Bertram and Stadler-Salt, 1998). The Pressure Indicator category is further sub-divided into Management Objectives indicators (used to measure progress toward the Lake Erie ecosystem management objectives) and Processes indicators (used to measure impacts to important ecosystem and economic processes). The State Indicators will be used to measure the current state of the various components of the Lake Erie ecosystem.

The six management objectives indicator categories – natural lands, nutrients, chemical contamination, biological contamination, resource use and disturbance and non-native invasive species – correspond directly to the LaMP ecosystem management objectives and will be used to report on the LaMP's progress in achieving the Lake Erie Vision.

The processes and state indicators provide a further level of detail that will allow the LaMP to go beyond reporting progress on achieving the vision, and will allow an evaluation of ecosystem components that are contributing to change, an evaluation of important components for reporting and long-term trends, and will provide predictive capacity.

3.5.3 Review of the Candidate Indicators

Each of the cells within the Lake Erie indicators matrix has been populated with candidate indicators that had been proposed by respondents of the questionnaire or during discussions of the Indicators Task Group. This "comprehensive matrix" includes all possible indicators, whether they are already in use elsewhere, currently in development or still need to be developed.

The next step is to refine the list of candidate indicators based on their feasibility specifically for use by the Lake Erie LaMP.

3.6 References

Bertram P. and N. Stadler-Salt. 1998. Selection of Indicators for Great Lakes Basin Ecosystem Health. SOLEC '98. 31pp + appendices.

Burns, N.M. 1985. Erie the Lake that Survived. Rowman and Allanheld. 320pp.

Colavecchia, M., S. Ludsin, P. Bertram, R. Knight, S. George, H. Biberhofer, and P. Ryan. 2000. Identification of ecosystem alternatives for Lake Erie to support development of ecosystem objectives. Lake Erie LaMP Technical Report Series.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5:55-68.

Ricciardi, A. 2001. Facilitative interactions among aquatic invaders: Is an "invasional meltdown" occurring in the Great Lakes? Can. J. Fish. Aquat. Sci. 58:2513–2525.

Photo: Grand River Conservation Authority

Section 4: Synthesis of Beneficial Use Impairment Assessment Conclusions

4.1 Introduction

Scope

Annex 2 of the Great Lakes Water Quality Agreement requires that each LaMP assess impairment to14 beneficial water resource uses as the first step in identifying restoration and protection actions for each of the Great Lakes. The 14 beneficial use impairments and the criteria for determining impairment are outlined in Table 2.1. The Lake Erie LaMP also recognizes that more than just these 14 beneficial use impairments will need to be addressed before Lake Erie can be fully restored. These other issues, or stressors, are discussed in other sections of the LaMP document.

Experts in each respective impairment area completed beneficial use impairment assessments over several years (Table 4.1). The geographic scope of the impairment assessment includes the open waters of Lake Erie, nearshore areas, embayments, river mouths and the lake effect zones of all Lake Erie tributaries. The location of the cause or source of the impairment does not have to fall within the above-mentioned geographic boundaries to be considered within the LaMP evaluation process. **When an impaired beneficial use is identified in a particular basin in the summary tables throughout this section, it means that impairment is occurring somewhere in that basin, not necessarily throughout the entire basin referenced.**

Table 4.1: Summary of Lake Erie LaMP Beneficial Use Impairment Assessment Reports Completed

Use Impairment	Impairment Conclusion	Assessment Completed	Authors
Fish & Wildlife Consumption Restrictions	Impaired	1998	Lauren Lambert, Ohio EPA
Tainting of Fish & Wildlife Flavor	Not Impaired	1997	Lauren Lambert, Ohio EPA
Degradation of Fish Populations	Impaired	1999	Roger Knight, Ohio DNR and Phil Ryan, Ontario MNR
Degradation of Wildlife Populations and Loss of Wildlife Habitat	Impaired	2001	Lauren Lambert, Ohio EPA; Jeff Robinson, Canadian Wildlife Service; Mark Shieldcastle, Ohio DNR; Madeline Austin, Environment Canada
Fish Tumors or Other Deformities	Impaired	2000	Paul Baumann, USGS; Victor Cairns, Fisheries and Oceans Canada; Bill Kurey, US Fish and Wildlife Service; Lauren Lambert and Roger Thoma, Ohio EPA; Ian Smith, Ontario MOE
Animal Deformities or Reproduction Problems	Impaired	2000	Keith Grasman, Wright State University; Christine Bishop, Canadian Wildlife Service; William Bowerman, Clemson University; James Ludwig, SERE Group; Pamela Martin, Canadian Wildlife Service; Lauren Lambert, Ohio EPA
Degradation of Benthos	Impaired	2001	Jan Ciborowski, University of Windsor
Restrictions on Dredging Activities	Impaired	1997	Julie Letterhos and Kurt Kohler, Ohio EPA
Eutrophication or Undesirable Algae	Impaired	1999	Serge L'Italien, Murray Charleton and Mike Zarull, Environment Canada; Todd Howell, Ontario MOE; Paul Bertram, USEPA-GLNPO; Roger Thoma, Ohio EPA
Restrictions on Drinking Water Consumption or Taste & Odor Problems	Not Impaired	1997	Lisa Thorstenberg, U.S. EPA and Serge L'Italien, Environment Canada
Recreational Water Quality Impairments	Impaired	1999	Beth Kwavnick, Health Canada; and Joyce Mortimer, Health Canada
Degradation of Aesthetics	Impaired	1997	Lauren Lambert, Ohio EPA
Added Costs to Agriculture or Industry	Not Impaired	2000	Lauren Lambert, Ohio EPA
Degradation of Phytoplankton & Zooplankton Populations	Impaired	1998	Ora Johannsson, Fisheries and Oceans Canada and Scott Millard, Environment Canada
Loss of Fish Habitat	Impaired	1998	Larry Halyk, Ontario MNR and David Davies, Ohio DNR

The Ecosystem Approach in Action - Step 1

For the Lake Erie LaMP, the term ecosystem approach means: a) remediating both contaminant and noncontaminant causes of impairment is important to the restoration of Lake Erie, and b) management actions must consider impacts to all key components of the Lake Erie ecosystem before they are implemented.

In keeping with item "a", this beneficial use impairment assessment treats all impairments and known causes equally, regardless of the type, severity, duration, trend, geographic extent, or magnitude. The primary causes of impairment are chemical contaminants, habitat loss and degradation, exotic species, and the associated impacts to energy and contaminant flow in the food web. Remediation of any one of these causes without addressing the others will not fully restore Lake Erie.

In terms of item "b", existing objectives such as those in the North American Waterfowl Management Plan (NAWMP), the National Shorebird Plan, Partners in Flight and the Lake Erie Fish Community Goals and Objectives (FCGO) were used to complete the beneficial use impairment assessment. Some of these existing objectives were developed with primarily one group of organisms in mind, and not necessarily the entire ecological community. In the case of wildlife, most of the objectives are not Lake Erie specific. It is important to use and fine tune existing objectives with new proposed objectives to prevent conflicting management actions. An example of such a conflict is diking wetlands to protect wildlife habitat from destruction by lake wave action, but consequently isolating the wetland from use as a spawning and nursery area for lake fish.

The Lake Erie LaMP has developed a vision and ecosystem management objectives, described in Section 3 of this document, that will allow us to explore the effects of changes in management strategies on all parts of the ecosystem. These ecosystem management objectives set the stage to prioritize actions that must be implemented to restore beneficial uses.

Synthesis Approach

It is recognized that many improvements already have occurred in the Lake Erie environment. This section of the document summarizes the problems that still exist and that the LaMP must address. The impairment conclusions for each of the Lake Erie assessments are summarized in tables within each subsection and serve as the preliminary problem definition for the lake. Eleven of the assessments concluded that impairment is occurring somewhere within the geographic scope of the Lake Erie LaMP.

In general, more impairments are identified in the western basin and in the lake effect zones of tributaries than in the other two basins. However, this fact must be interpreted carefully. While it is known that contaminant impacts are generally greatest in the western basin, there are several other key considerations. The range of certain sensitive species is limited to the western basin and acreage of certain habitat types was historically greatest in the western basin. For example, in terms of impacts to coastal wetlands, the former Black Swamp alone covered nearly 300,000 acres before land use changes reduced the remaining acreage to the current 30,000 acres. In other cases most of the data were collected from the western basin. Because the states and province are responsible for regulating surface waters in their respective jurisdictions, an abundance of tributary data is available. Seven of the 12 Lake Erie basin AOCs are located in the western basin or watershed and have already completed extensive beneficial use impairment assessments for those specific geographic areas. And finally, certain impairments are limited to tributaries and nearshore areas by default (e.g. beach impairments, restrictions on dredging activities and many of the habitat impairments).

The purpose of this section is to briefly synthesize the assessments by linking the impairment conclusions, causes, and trends among impairments. Impairment assessment conclusions have been grouped into three broad categories based on the primary areas of public interest to date: human use impairments (section 4.2), impairments due to chemical contaminants (section 4.3), and ecological impairments (section 4.4), with a synthesis narrative for each. All the original beneficial use assessments were completed between 1997 and 2001. Some updates as of 2004 are added, but no impairment assessment conclusions have changed. As the ecosystem of Lake Erie changes over time, periodic re-assessments of each beneficial use will be needed. **The LaMP hopes to have all beneficial use impairments re-assessed by 2008. The research needs and data gaps presented in the 2000 report have been removed from this section to be incorporated into a Lake Erie LaMP research and monitoring agenda that is being drafted as part of the 2004-2006 Paths to Achievement (workplan).**

More detailed technical information is available at www.epa.gov/glnpo/lakeerie/buia/index.html.

4.2 Human Use Impairments

The human use assessment results answer the questions, are Lake Erie waters: a) fishable, b) swimmable, c) drinkable, d) navigable, and e) clean enough for routine agricultural and industrial use? The impairment conclusions for each are summarized in Table 4.2 and show that Lake Erie waters are not yet completely fishable, navigable, and swimmable. The major causes of these impairments to human use are chemical contaminants and elevated levels of bacteria in recreational waters.

Table 4.2: Summary of Human Use Impairments *(updated 2004)*

Impaired Use	Impairment Conclusions by Basin	Causes of Impairment
Fish and Wildlife Consumption Restrictions	*FISH* - **Impaired** in all basins. *WILDLIFE* - **Impaired** in eastern basin; inconclusive for western and central basins. **UPDATE 2004**: FISH* - sport fish consumption advisories in open and tributary waters of all basins. WILDLIFE - consumption advisories for snapping turtles in NY and OH and waterfowl in NY.	*FISH* - PCBs, mercury, lead and dioxins *WILDLIFE* - PCBs, chlordane, DDT and mirex **UPDATE 2004:** FISH - no change WILDLIFE - PCBs, chlordane, DDT, mirex, *mercury, lead*
Tainting of Fish and Wildlife Flavor	Not Impaired **UPDATE 2004**: no change	None **UPDATE 2004**: no change
Restrictions on Dredging Activities	**Impaired** in tributary mouths and harbors of all basins. Confined disposal is required in certain areas. **UPDATE 2004:** No change	PCBs, heavy metals **UPDATE 2004:** PCBs, heavy metals, PAHs
Restrictions on Drinking Water Consumption or Taste and Odor Problems	Not Impaired **UPDATE 2004**: no change	None **UPDATE 2004**: no change
Recreational Water Quality Impairments	**Impaired** in nearshore waters of all basins; Inconclusive for offshore waters of all basins. **UPDATE 2004:** Nearshore areas in all basins. Exceedances of bacterial guidelines established to protect human health.	Exceedances of *E. coli* and/or fecal coliform guidelines, PAHs+, PCBs+ **UPDATE 2004:** Contact advisory for Black River AOC lifted in 2004
Degradation of Aesthetics	**Impaired** in nearshore waters, all basins; Inconclusive for open waters of the western basin (Table 4.4). **UPDATE 2004:** High turbidity; obnoxious odors; decaying *Cladophora* on the shoreline; seasonal fish die-offs of non-native alewife and gizzard shad; hindrances to recreational use due to floating garbage, debris and zebra mussels.	Excessive *Cladophora*, point/non-point source stormwater runoff, floating garbage and debris, dead fish, excessive zebra mussels on beaches **UPDATE 2004**: no change
Added Costs to Agriculture and Industry	Not Impaired **UPDATE 2004:** no change	None **UPDATE 2004**: no change

*Commercial fishermen in Ontario are prohibited from selling carp that are 32 cm or larger, due to PCBs.

+ PAHs are the basis for a human contact advisory in the Black River (OH) AOC and PCBs are the basis for a human contact advisory in the Ottawa River (Maumee AOC). These advisories were issued by the Ohio Department of Health and mean that contact with sediment or water in these areas should be avoided.

Photo: Upper Thames River Conservation Authority

4.2.1 Summary of the 1998 Fish Consumption Restrictions Beneficial Use Impairment Assessment

Eating fish is an important part of a well-balanced diet. However, it is important to be aware of restrictions that may be in place for certain species, certain areas and when eating larger fish.

Fish consumption impairments occur when contaminant levels in fish exceed current standards, objectives or guidelines, or public health advisories are in effect for human consumption of fish or wildlife. Impairment to human consumption of Lake Erie fish is occurring. Public health advisories for human consumption of sport fish are in place for many geographic locations within Lake Erie waters.

Particularly noteworthy from the 1998 assessment were "DO NOT EAT" consumption advisories for certain species/size classes of fish in Lake Erie, Maumee and Long Point Bays, the Maumee, Ottawa, Detroit, Raisin and Rouge Rivers, and the Buffalo River/Harbor area. In addition, commercial fishermen in Ontario were prohibited from harvesting carp that are 32 cm or larger, due to PCBs. Since the original assessment, there is also now a "DO NOT EAT" advisory for carp >75cm in Wheatley Harbour, for walleye >65cm in the Detroit River, and commercial fishermen in Ontario are only permitted to harvest channel catfish 33cm or smaller. The "DO NOT EAT" advisory on the Rouge River was changed to a less restrictive advisory following a PCB-contaminated sediment remediation project.

The presence of contaminants in Lake Erie, which are the basis for these advisories, exceed the Great Lakes Fisheries Commission's Lake Erie Committee (LEC) draft objective related to fish consumption advisories. The goal of this objective is to "reduce contaminants in all fish species to levels that require **no advisory** for human consumption." The existence of fish consumption advisories also does not meet the IJC objective of no restrictions on the human consumption of fish in waters of the Great Lakes Basin Ecosystem.

Table 4.3: Summary of Sport Fish Consumption Advisories by Lake Erie Basin

Basin	Sport Fish Consumption Advisory
Western Basin Nearshore	Impaired. Fish advisories for Maumee, Portage, Sandusky, Raisin, Rouge, Detroit, and Ottawa River tributaries, and Wheatley Harbor and Maumee Bay. **Update 2004: no change**
Western Basin Offshore	Impaired. Fish advisories for Lake Erie waters of all jurisdictions bordering this basin. **Update 2004: no change**
Central Basin Nearshore	Impaired. Fish advisories for Vermilion, Huron, Black, Cuyahoga, Ashtabula, and Chagrin Rivers, Conneaut Creek tributaries and Rondeau Bay. **Update 2004:** Add Grand River (OH)
Central Basin Offshore	Impaired. Fish advisories for Lake Erie waters of all jurisdictions bordering this basin. **Update 2004: no change**
Eastern Basin Nearshore	Impaired. Fish advisories for Presque Isle Bay, Buffalo River/Harbor, Grand River, Ontario, Big Creek, and Long Point Bay. **Update 2004: no change**
Eastern Basin Offshore	Impaired. Fish advisories for Lake Erie waters of all jurisdictions bordering this basin. **Update 2004: no change**

Fish consumption advisories are issued to assist sport fish consumers in protecting their health. The goal of advisories is to minimize human exposure to chemical contaminants that are present in fish tissue. The choice of which fish to consume, how frequently to consume, and how to prepare it, remains with the individual. In contrast, commercial fishing restrictions are enforceable standards and are therefore mandatory.

The most common chemical causes of sport fish consumption advisories are PCBs and mercury, although advisories in some areas are issued due to lead and dioxins. Additional chemical parameters that are routinely monitored vary by jurisdiction. Sport fish consumption advisories are educational tools that not only identify geographic locations where fish are affected, but also inform consumers of fish species and size classes likely to contain higher levels of chemical contaminants, offer recommendations on frequency of consumption, and recommend preparation and cooking techniques that reduce risk of exposure to contaminants that accumulate in fatty tissues, such as PCBs. The presence of mercury in fish has been of particular concern because it accumulates in the tissue of fish rather than the fat. Food preparation methods such as trimming fat and skin, and broiling rather than frying do not reduce exposure to mercury. The only effective option to minimize exposure to mercury present in fish tissue is to follow fish consumption advisories and to avoid eating the internal organs of the fish.

As an example of jurisdictional efforts to address the mercury concern, in 1997 Ohio issued a general precautionary consumption advisory for women of childbearing age and children age 6 and under. They were advised to eat no more than one meal per week of any fish species from any Ohio body of water. In 2003, the advisory was extended to everyone. This was due to the presence of mercury at low background levels in nearly all Ohio fish samples tested. Due to frequency of consumption or traditional ethnic means of food preparation, subsistence anglers and certain cultural and immigrant groups may also be at greater risk of adverse effects due to contaminant exposure. More restrictive consumption frequency advisories are issued for these groups, such as the Ontario mercury advisory for subsistence fishers.

The United States Environmental Protection Agency in 2001 issued a national mercury-based advisory that states: "If you are pregnant or could become pregnant, are nursing a baby, or if you are feeding a young child, limit consumption of freshwater fish caught by family and friends to one meal a week. For adults, one meal is six ounces of cooked fish or eight ounces of uncooked fish; for a young child, one meal is two ounces of cooked fish or three ounces of uncooked fish."

In 2004, the Food and Drug Administration (FDA) and U.S. EPA issued a nationwide joint consumer advisory on methylmercury in fish and shellfish that supersedes the 2001 advisory. The FDA and U.S. EPA want to emphasize the benefits of eating fish but suggest that women might wish to modify the amount and type of fish they consume if they are pregnant, planning to become pregnant, nursing, or feeding a small child. The advisory specifically lists species of fish and shellfish not to eat (shark, swordfish, king mackerel, tilefish). It advises eating up to 12 ounces a week of the more commonly eaten species that are lower in mercury (shrimp, canned light tuna, salmon, Pollock, catfish), and six ounces per week of albacore tuna. The third part of the advisory recommends to: "Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers and coastal areas. If no advice is available, eat up to six ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week. Follow these same recommendations when feeding fish and shellfish to your young child, but serve smaller portions."

Carp is the fish species most frequently identified in Lake Erie consumption advisories, although numerous other species are identified in various locations, particularly channel catfish and freshwater drum. The different species restrictions apply to particular sizes of fish, based on the results of fish tissue sampling and varying rates of bioaccumulation.

Since the BUIA for fish consumption was completed in 1998, the impairment status and chemicals of concern for fish consumption advisories have not changed. It appears that chlordane was listed as a cause of impairment in the LaMP 2000 report due to advisories in Pennsylvania. Pennsylvania continues to monitor for chlordane, but PCBs and mercury are now the contaminants upon which advisories are based. What has changed, however, are the number and sizes of species listed and an expansion of the areas where fish consumption advisories are now in effect. In many cases the list of advisories has increased due to collection and examination of fish tissue from new areas, rather than new sources of contamination. Mercury has become fairly ubiquitous, even in areas where there are no direct sources, suggesting that atmospheric deposition is the probable cause. Most jurisdictions now have a general advisory to eat no more than one meal per week of fish from waters in their borders.

Web sites for each of the Lake Erie jurisdictions maintain current information on fish consumption advisories in their state or province. Check the following for specific information:

Michigan: www.michigan.gov/documents/FishAdvisory03_67354_7.pdf
New York: www.health.state.ny.us/nysdoh/fish/fish.htm
Ohio: www.epa.state.oh.us/dsw/fishadvisory/index.html
Pennsylvania: www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/FishAdvis/fishadvisory04.htm
Ontario: www.ene.gov.on.ca/envision/guide/index.htm

4.2.2 Summary of 1998 Wildlife Consumption Restrictions Beneficial Use Impairment Assessment

Wildlife contaminant research has been extensive in the Great Lakes, but generally as it pertains to wildlife, not human health. Of the Lake Erie jurisdictions, only New York has established criteria for implementing wildlife consumption restrictions, although Ontario and Michigan have done research to evaluate the potential need for consumption advisories for waterfowl. Public health advisories for human consumption of snapping turtles and waterfowl are in place statewide for New York. The contaminants causing these advisories are PCBs, mirex, chlordane, and DDT (New York State Department of Health 2002)

Update 2004

In 2002 and 2003, Ohio listed consumption advisories for snapping turtles in certain Lake Erie tributaries due to mercury, lead and PCBs.

Photo: Scott Gillingwater

4.2.3 Summary of 1997 Restrictions on Dredging Activity Beneficial Use Impairment Assessment

Between 1984 and 1995, 25 navigational areas around Lake Erie have been dredged. Twelve of the 25 areas that are dredged have required the dredged material to be disposed in a confined disposal facility (CDF) at some time during this period. Currently, seven of these sites (Ashtabula, Cleveland, Lorain, and Toledo, Ohio, and Detroit, Rouge River and Monroe, Michigan) require confined disposal for most of the sediment dredged from those areas. Because there are restrictions on disposal of dredged materials, this use is considered impaired. Water quality standards and criteria for disposal of sediments vary among jurisdictions, but throughout the basin PCBs, PAHs and heavy metals are the most commonly identified contaminants that dictate confined disposal. A PAH-contaminated site in the Black River (OH) was remediated in 1990 by dredging and remedial dredging is planned in at least three other sites around the basin.

Table 4.4: Summary of Lake Erie Navigational Dredging Activity 1984-1995, by Jurisdiction

Jurisdiction	Michigan	New York	Ohio	Ontario	Pennsylvania
# of Locations	4 locations 3 AOCs	1 location 0 AOCs	12 locations 4 AOCs	7 locations 1 AOC	1 location 1 AOC
Volume (cu. yd.)	3,585,200	101,400	20,928,600	788,135	177,800
Cost	$25,642,900	$382,800	$71,007,700	$4,801,400	$502,300

2004 Update

A PCB-contaminated sediment remediation project was completed on the Rouge River in 2001. PCBs in fish have subsequently been reduced enough to change the "DO NOT EAT" advisory to a less restrictive one. One sediment remediation project on the River Raisin has been completed and another is underway along with additional sediment assessments. Another remediation project is underway on Harris Lake in the Clinton River AOC. An extensive sediment assessment project, particularly to document high levels of PAHs as the cause of a high incidence of tumors in bullhead, was completed on the Old Channel of the Cuyahoga River in 2003.

4.2.4 Summary of 1999 Recreational Water Quality Beneficial Use Impairment Assessment

Annex 1 of the Great Lakes Water Quality Agreement (GLWQA) states that: *"Waters used for body contact recreation activities should be substantially free from bacteria, fungi, or viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections or other human diseases and infections"* (IJC, 1989). Annex 2 of the GLWQA lists "beach closings" as a beneficial use impairment related to recreational waters. According to the IJC, a beach closing impairment occurs "*when waters, which are commonly used for total body contact or partial body contact recreation, exceed standards, objectives, or guidelines for such use*" (IJC, 1989).

The major human health concern for recreational use of Lake Erie waters is microbiological contamination (bacteria, fungi, viruses, and parasites). Human exposure occurs primarily through ingestion of polluted water, and can also occur through the entry of water into the ears, eyes, nose, broken skin, and through contact with the skin. Gastrointestinal disorders and minor skin, eye, ear, nose and throat infections have been associated with microbiological contamination.

As noted above, recreational water quality impairment includes situations where partial body contact recreation standards are exceeded. To be complete, an assessment needs to evaluate all recreational water use activities where total or partial body water contact may occur. This includes primary activities such as swimming, windsurfing and water skiing, and also situations where swimming may occur in open waters during secondary contact activities, such as boating and fishing. The assessment considers both nearshore and open water activities in its evaluation of impairment, thus, the change in title from *beach closings* to *recreational water quality impairments*.

Federal, state and provincial recreational water quality guidelines recommend bacterial levels below which the risk of human illness is considered to be minimal. When contaminant indicator levels in the bathing beach water reach levels that indicate contaminants may pose a risk to health, public beaches are posted with a sign warning bathers of the potential health risk. The primary tool to evaluate beach water quality is the measurement of *indicator organisms*, which indicate the level of bacterial contamination of the water. The two indicator organisms most commonly used to measure bacterial levels are *fecal coliform* and *Escherichia coli* (*E.coli).* High levels of fecal coliform or *E. coli* in recreational water are indicative of fecal contamination and the possible presence of intestinal-disease-causing organisms. However, it should be noted that neither *E. coli* nor fecal coliform testing differentiates between human or animal waste, or indicates the presence of viruses or of non-fecal contaminants (e.g. *Staphylococcus*).

Bacterial level exceedences are occurring at beaches throughout the Lake Erie basin. Therefore, Lake Erie basin nearshore recreational water quality is impaired from a human health (i.e. bathing use) standpoint. Bacterial levels data examined for the 1998 BUIA report provided support for a conclusion that recreational use of Lake Erie offshore is unlikely to be impaired by bacteria. However, based on a request from the Lake Erie Binational Public Forum, the Lake Erie LaMP has decided to classify the use impairment for recreationally used "open waters" as "inconclusive", since a recent comprehensive data-set for open lake waters is not available for assessment.

Photo: U.S. EPA Great Lakes National Program Office

Many sources contribute to microbiological contamination, including combined or sanitary sewer overflows, unsewered residential and commercial areas, and failing private, household and commercial septic systems. However, it is important to note that simply because bacterial levels are present, it does not necessarily mean that sewage overflow is a problem. Other sources may be agricultural runoff (e.g. manure); fecal coliforms from animal/pet fecal waste washed into the lake or storm sewers by heavy rains; wildlife waste, as from large populations of gulls or geese fouling the beach; direct human contact, e.g. swimmers with illnesses, cuts or sores; or high numbers of swimmers/bathers in the water, which are related to increased bacterial levels; and direct discharges, illegal dumping of holding tanks of recreational vessels. Other factors affecting contamination levels are low (shallow) water levels; hot weather/higher temperatures; high winds that can stir up bacteria that are in the sediments; and calmer waters that can slow dispersal and create excess concentrations of bacteria.

Update 2004

Many beaches still experience beach closings throughout the recreational season. The U.S. Beach Act provides grants to the states to develop regular monitoring programs and the use of common standards to determine when a beach should be closed. A number of research studies are underway to define sources of beach contamination and also to develop monitoring methods that provide more timely results.

4.2.5 Summary of 1997 Degradation of Aesthetics Beneficial Use Impairment Assessment

An aesthetic impairment occurs when any substance in water produces a persistent objectionable deposit, unnatural color or turbidity, or unnatural odor (e.g. oil slick, surface scum) (IJC, 1989).

For the Lake Erie LaMP process, the IJC listing criteria for evaluating aesthetic impairments in Lake Erie have been adopted with the following additions:

- Whether an aesthetic problem is *naturally* occurring or *man-made* does not affect its potential designation as an impairment;
- The fact that there is currently no known solution to an aesthetic problem does not affect its potential designation as impairment.

With the exception of beneficial use impairment assessments already completed for Lake Erie AOCs, Lake Erie aesthetic problems have not previously been evaluated collectively. In most cases the locations, frequency, duration, and magnitude of any identified aesthetic problems or impairments have not been regularly tracked through any formal monitoring program. In addition, there is no precise/common definition for a "persistent objectionable deposit." Therefore, detailed information is largely anecdotal and inherently subjective.

The purpose of this assessment is to: a) outline all known instances of aesthetics problems in Lake Erie waters; b) evaluate the nature of these problems, where possible; and c) to distinguish between aesthetic impairments to use of Lake Erie, as defined by the IJC listing criteria, and other aesthetic issues of concern that do not meet the listing criteria.

The reappearance of the mayfly (*Hexagenia*) exemplifies the conflict between traditional indicators of improving ecosystem quality and perceived aesthetic problems. During the final stage of their life cycle, burrowing mayflies emerge from Lake Erie sediments and swarm in such large numbers that they have made roads slippery and caused temporary brown-outs. These swarms of mayflies are regarded as a signal of improving Lake Erie water quality, but create a temporary nuisance to humans. Because the mayfly is widely regarded as a signal of improving water quality, any aesthetic problems created by swarming have not been classified as an impairment in this assessment. However, it is acknowledged that there can be temporary conflicts between the improving Lake Erie ecosystem and certain desired human uses of the lake region during the mayfly-swarming period.

To date, the Lake Erie LaMP process has identified the following list of potential aesthetic problems: high turbidity, obnoxious odor, excessive *Cladophora,* excessive blue-green algae, nuisance conditions at public beaches/lake shoreline, excessive aquatic plants washing up onto beaches and shorelines, floating garbage/debris, and dead fish.

4.3 Impairments Caused by Chemical Contaminants

4.3.1 Overview

Both contaminant loadings to the lake and contaminant levels in biota have decreased from levels recorded in the 1960s and 1970s. However, Lake Erie still contains a legacy from the past in the form of contaminated sediments that were deposited before bans on the use of certain chemicals and pollution reduction initiatives were implemented. Contaminants are clearly bioaccumulating in Lake Erie biota on a continuum from benthos to fish to amphibians, reptiles, birds and mammals, resulting in the specific impairments summarized in Tables 4.5 through 4.7. In addition, the filter feeding habits of the non-native invasive dreissenids are re-introducing contaminants not previously biologically available back into the water column and ultimately into the food web.

The information in this section is organized by trophic level (benthos, fish, birds, and mammals) to more clearly illustrate the biomagnification concept. Benthic organisms spend most or all of their lifecycle in the sediment of the lake. Some fish are benthic feeders or spend most of the time near the bottom; others eat organisms that have spent part of their lifecycle as benthos. Finally, birds and mammals prey on the fish. Each organism has

4.2.5.1 Impairment Conclusions

Table 4.5: Summary of 1997 Lake Erie Aesthetic Impairment Conclusions

Type of Impairment	Determination of Impairment	Location/Extent of Impairment	Known Causes of Impairment	Notes
High Turbidity	**Impaired**.	Maumee, Rouge River and River Raisin AOCs - western basin; Black and Cuyahoga (navigation channel) AOCs - central basin.	Agricultural and urban point and non-point source runoff and storms stirring up bottom sediments.	
Obnoxious Odors	**Impaired** due to dead fish and *Cladophora*; Inconclusive decaying zebra mussels.	Cuyahoga AOC - central basin (fish); *Cladophora* fouling has occurred at Lake Erie State Park Beach, New York and Rondeau Bay, Ontario.	Decaying algae and fish.	Although decaying zebra mussels and CSO discharges of raw sewage are known to cause obnoxious odors, it appears from information to date that these problems are not persistent in Lake Erie.
Excessive *Cladophora*	**Impaired.**	Eastern and central basin nearshore - nearshore and river mouths in Ontario waters (eastern basin) and Rondeau Bay, Ontario (central basin).	Nutrient enrichment, availability of substrate.	
Blue-green Algae	Inconclusive.	Western basin.	Emerging issue. Research is underway to pinpoint cause of *Microcystis* bloom. Hypothesis that zebra mussels may be contributing to the problem.	It is not known whether extensive *Microcystis* blooms will continue to persist. Therefore a definitive impairment determination has not been made.
Aquatic Plant Deposits at Public Beaches	Not Impaired/ No documentation to date showing a persistent problem.	N/A	N/A	
Zebra Mussel Shells at Public Beaches	Inconclusive.	Large deposits of shells have been reported at many western basin beaches and at Presque Isle Bay State Park, central basin.	Deposits of zebra mussels/ shells.	It is not known whether reported problems are persistent and, if so, if they are interfering with human use of shoreline areas.
Floating Garbage and Debris	**Impaired.**	Geographic extent of impairment is localized, Cuyahoga AOC, Headlands Dune State Nature Preserve - central basin.	Large quantities of floating debris (primarily natural), Cuyahoga AOC; interfering with navigational, recreational, and industrial use of affected area in Cuyahoga AOC. Large quantities of floating garbage (primarily CSO-related) have led to citizen complaints at Headlands Dunes State Nature Preserve.	This issue is significant enough for the Cuyahoga AOC that a proposal to purchase a debris harvester is being pursued.
Dead Fish	**Impaired**.	Geographic extent of impairment is seasonal and localized. Cuyahoga AOC - central basin, Ontario eastern basin waters are only documented impairments to date.	Seasonal die-offs due to alewife/other exotics not acclimated to colder water temperatures.	

N/A = Not Applicable

bioaccumulated contaminants during its lifecycle, and the effect magnifies as one moves up the food chain. There are species used as indicators of this phenomenon (midges, mayflies, brown bullhead, bald eagle and herring gull) for which we have the most information. However, the list of species used to monitor contaminant impacts has grown in recognition of widespread bioaccumulation.

It should be noted that contaminant studies tend to look at effects to a particular organism in a particular location versus population-wide effects. But when evidence from the ecological impairments (section 4.4) is combined with toxicological results, it can be seen that contaminants are often an important limiting factor to population health.

4.3.2 Summary Conclusions

Lake Erie basin impairments caused by chemical contaminants include restrictions to fish and wildlife consumption, restrictions on dredging activity, fish tumors or other deformities (section 4.3.4), bird and animal deformities or reproduction problems (section 4.3.5), and benthic deformities (section 4.3.3). Impairment conclusions for restrictions to fish and wildlife consumption and restrictions on dredging activity are summarized in section 4.2, human use impairments. The rest are summarized below.

PAHs, PCBs, DDE, DDT, mercury, lead, chlordane, dioxins, mirex, dieldrin, and nitrates are all demonstrated to be causing impairment to fish and/or wildlife. As a result, most of these chemicals have already been identified as LaMP pollutants of concern for source trackdown. In particular, PCBs and mercury have been designated as critical pollutants for priority action in the Lake Erie LaMP.

4.3.3 Summary of 2001 Benthos Beneficial Use Impairment Assessment

Benthos refers to the suite of organisms that live on or in the lake bottom, referred to here as macroinvertebrates. Because macroinvertebrates live in close association with the sediments and are relatively immobile, they are good bioindicators of levels of persistent compounds in the sediments, especially trace metals and organic chemicals (pesticides, petrochemicals, PCBs, PAHs, etc.). Therefore, one of the criteria used for assessing benthic impairment is when toxicity of sediment-associated contaminants at a site is significantly higher than reference controls.

Highly toxic sediments produce profound, but sometimes non-specific, reductions in benthic abundance, richness (numbers of species), and community composition. Lower levels of contaminants may cause sublethal effects in invertebrates, just as they do in vertebrate animals (impairment of growth or development, morphological deformities, chromosomal abnormalities, or production of stress proteins). Contaminant breakdown products are often more toxic than the parent compounds. However, some benthos may tolerate persistent compounds because they lack the ability to break the pollutants down into compounds that can be excreted. Because benthic invertebrates may bioaccumulate these toxic compounds, their body burdens can serve as indicators of the amount of bioavailable contaminants in the environment, and of the transfer potential to predators at higher trophic levels (fishes, birds, etc.). Bioaccumulation factors for some chemicals can be extrapolated to anticipate whether burdens of top predators are likely to approach toxic thresholds.

For the Lake Erie LaMP assessment, the benthic communities found in contaminated sediments may be designated impaired if one or more of the following occur:

- The community is degraded;
- Bioassays using sediment from an area indicate toxicity to benthic organisms;
- Macroinvertebrates collected from the sediments have significantly elevated incidences of deformities or other abnormalities;
- The contaminant burden of benthic animals is great enough that predators may be at risk of bioaccumulating toxic concentrations of the contaminants.

Impairment was assessed in each of six lake zones: tributaries, wetlands, shorelands, embayments, nearshore and offshore. Conclusions, by basin and zone, for benthic impairments due to contaminated sediments are summarized in Table 4.6. Benthic impairments that are due to causes other than contaminated sediments are addressed in section 4.4.

Table 4.6: 2001 Summary of Benthic Impairments Caused by Contaminated Sediments

Lake Erie Zone	Lake Erie Basin	Type of Impairment
Tributaries	Eastern - Buffalo River	Contaminated sediments; elevated incidence of mouthpart deformities in midges
	Eastern - Grand River, Ontario	Chemical contamination
	Central - Black, Cuyahoga and Ashtabula Rivers	Contaminated sediments
	Western - Detroit, Raisin, Ottawa and Maumee Rivers and Swan Creek	Contaminated sediments
Embayments	Central - Black, Cuyahoga and Ashtabula Rivers	Harbors dominated by pollution tolerant benthos
	Western - Maumee Bay, Toledo Harbor	Contaminated sediments
Nearshore *(< 5 m depth water up to 4 km from shore)*	Western - Detroit and Maumee Rivers	Elevated incidence of mouthpart deformities in midges
Offshore *(> 4 km from shore)*	Western - Detroit River discharge current	Low *Hexagenia* population density appears to parallel discharge current band; this needs to be confirmed with maps
	Western - Monroe	Adult *Hexagenia* collected in 1994 had the highest contaminant burdens (PCBs, other organochlorines, pesticides) of any Lake Erie samples
	Western - Middle Sister Island	*Hexagenia* larvae had high burdens of organochlorines and PAHs

4.3.4 Fish Contaminants

4.3.4.1 Overview

In Lake Erie and its tributaries, mercury, PCBs, lead and dioxins are causing fish consumption advisories. PAHs, and potentially other compounds, in contaminated sediments are associated with fish tumors and other deformities. The purpose of fish consumption advisories is to minimize potential adverse impacts to human health (section 4.2). However, the contaminant data that support the advisories can also be used as a tool to assess fish and wildlife health. For example, contaminant levels in fish are used to develop bioaccumulation factors used in assessing contaminant impacts to fish-eating birds, mammals, amphibians, and reptiles (see section 4.3.3).

The purpose of assessing the prevalence of fish tumors and other physical abnormalities is to use these as an indicator of both environmental degradation of the aquatic ecosystem and a measure of health impairment to fish populations. However, this assessment of fish health is limited to fish deformities caused by xenobiotics such as PAHs, which do not bioaccumulate. Therefore, the potential impacts of bioaccumulative chemicals on other aspects of fish health, such as reproduction, are not covered. The LaMP acknowledges this data gap and hopes to address it in more detail in the future.

The assessment criteria require identification of fish tumor or deformity impairments: a) regardless of whether a specific cause for the tumor has been identified, b) regardless of whether a cause, when identified, is a chemical pollutant and/or carcinogenic, and c) regardless of whether a tumor is a carcinoma. Only data for types of tumors suitable as impairment indicators were used for this assessment (excludes genetically and virally induced tumors). All sites where fish tumor data suitable for indicating impairment existed, and tumor prevalence exceeded rates at least impacted sites in the Lake Erie basin, were classified as impaired as summarized in Table 4.7.

Where brown bullhead tumor impairment occurs, it is typically correlated with elevated concentrations of PAHs. Because brown bullhead are benthic fish and remain in a specific geographic location during their lifespan, tumors are indicative of local sediment conditions.

In surveys of other fish species, although the causes of tumor or deformity impairment are unknown, the presence of more mobile fish species points to broader environmental degradation (versus locally contaminated sediments) as the source of the problem.

Update 2004

Following the 1990 removal of PAH-contaminated sediments from the lower Black River (OH), tumors in brown bullhead have improved to the point that the RAP has submitted an application to U.S. EPA to re-designate the fish tumor BUIA from impaired to “in recovery”. While the exact cause(s) of the tumors in brown bullhead in the Presque Isle Bay (PA) AOC remains unclear, the tumor rates have improved to the point that the AOC is now rated as an “Area in Recovery.”

Table 4.7: Summary of Fish Tumor or Deformity Impairments from BUIA (Baumann et al. 2000)

Basin	Impairment
Western Basin Nearshore	**Impaired** in 6 tributaries, the Lake Erie islands, and along the Lake Erie shoreline in 2 Ohio counties
Western Basin Offshore	No conclusive documentation of impairment (e.g. freshwater drum tumors)
Central Basin Nearshore	**Impaired** in 13 tributaries, 1 bay, and along the Lake Erie shoreline in 4 Ohio counties
Central Basin Offshore	No data available to assess impairment
Eastern Basin Nearshore	**Impaired** in 1 tributary and 1 bay
Eastern Basin Offshore	No conclusive documentation of impairment (e.g. freshwater drum tumors)

4.3.5 Summary of Animal Deformities or Reproductive Problems Beneficial Use Impairment Assessment (Grasman et al. 2000)

Toxicological wildlife survey data are used throughout the Great Lakes to confirm the presence of deformities or other reproductive problems in sentinel wildlife species in a particular location. Therefore, by definition, the presence of these problems is enough evidence to confirm that impairment is occurring and is a good indicator of both wildlife health and potential adverse impacts due to contaminants. This assessment is not intended to assess population-wide impairments. Those issues are covered in the degradation of wildlife populations' assessment (see Table 4.8).

Because wildlife toxicology surveys are often designed to determine conditions in the Great Lakes basin as a whole, this assessment varies from others in the amount of Lake Erie specific data available and its ability to report results by Lake Erie basin. In addition, the Lake Erie basin populations of some of the species examined such as bald eagle and colonial waterbirds nest primarily in the western basin. Others such as the river otter were extirpated from the Lake Erie basin prior to the 1900s and have only recently been reintroduced by wildlife management agencies. The most abundant data are available for Lake Erie bald eagle and herring gull populations that have been surveyed annually since 1980 and the early 1970s, respectively.

A combination of lowest observable effect concentrations (LOECs), population recovery objectives, and physiological biomarkers were used to establish the scientific weight of evidence for impairment. Ecoepidemiological criteria were used to establish cause-effect linkages, where possible. Reproductive, deformity, and physiological impairments are identified and associated with chemical causes, where known, in Table 4.8. These results indicate that some type of impairment is either clearly or likely occurring in all groups assessed, except for tree swallows. As noted below, tree swallows are very resistant to the effects of chemical contaminants, and may therefore be a poor indicator species.

As noted earlier, per the IJC listing criteria, this assessment is not required or intended to determine whether population-wide effects are occurring due to the identified impairments. Reproductive effects do not immediately or always translate into population effects. For example, if a population is near its carrying capacity (point at which species is in equilibrium with its environment), then there may not be enough resources (food, nesting habitat, etc.) for all young to survive to reproductive age. Hence, up to a point, a decrease in production

Table 4.8: Summary of Bird and Animal Deformity or Reproductive Beneficial Use Impairment Assessment Completed in 2000

Species/ Species Group	Impaired?	Type of Impairment	Likely Cause*	Notes
Bald Eagle	**Yes**, observed; exposure above effect levels	Reproductive & Deformity	**R** - PCBs, dieldrin, DDE **D** - PCBs	Extent of impairment is probably obscured by hacking/fostering and immigration from less contaminated inland territories
Colonial Waterbirds (herring gulls, double-crested cormorants, common and Caspian terns)	**Yes**, observed in herring gulls; exposure above effect levels in herring gull, cormorant and common tern eggs	Reproductive, Deformity and Physiological - immune system, reproductive organs, thyroids, liver enzymes, vitamin A, and porphyrins**	**R** - PCBs and possibly other chemicals **D** - PCBs **P** - PCBs, other organochlorines	Cause of recent reproductive failures of herring gulls on W. Sister Is. may include PCBs, microcystin, and (or) other factors Tree nesting cormorants are hard to study, but contaminant concentrations are among highest in Great Lakes and are likely associated with embryonic mortality and deformities Although Caspian terns have attempted to colonize Lake Erie as recently as 1996, they are still too rare in the basin for field study
Tree Swallow	Possible	Possible Physiological - reduced Liver vitamin A	**P** - PCBs	Significant organochlorine exposure; resistance to effects may make swallow a poor indicator species compared to other insect-eating songbirds
Mink	Likely; PCBs in food above effect levels	Likely Reproductive and Physiological	**R** - PCBs **P** - no data	
Otter	Insufficient data, but likely based on predicted high levels of exposure	Likely Reproductive	**R** - PCBs	Too rare in Lake Erie basin for study as they have just recently been re-introduced
Snapping Turtle	Likely - not observed, but exposure at some Ohio sites above effect levels	Likely Reproductive, Deformity, Physiological	**R** - PCBs, other organochlorines **D** - PCBs, other organochlorines **P** - organochlorines	
Spiny Softshell Turtle	**Yes**, observed; exposure above effect levels	Reproductive	**R** - PCBs, other organochlorines	
Frogs/Toads	Likely (see notes)	Likely Reproductive	**R** - DDE, nitrates	Nitrate concentrations in Lake Erie watershed often exceed lethal and sublethal concentrations for amphibians studied in laboratory experiments
Mudpuppies	**Yes**, observed	Deformity	**D** - PAHs and organochlorines	

* R= Reproductive Impairment; D = Deformity Impairment; P = Physiological Impairment
** Porphyrins - the liver synthesizes heme for hemoglobin and certain enzymes. Some organochlorines block this process by causingthe accumulation of highly carboxylated porphyrins.

of young due to a contaminant may not affect adult population size because many young would have died anyway. However, if the population is below its carrying capacity, a decrease in production of young may prevent the population from reaching carrying capacity. In this situation, the impairments summarized in Table 4.8 can become more significant when all stressors to a particular species group are summed (contaminants, habitat loss, exotics, etc.). It is interesting to note that the results of the degradation of wildlife populations' assessment for these same groups of animals conclude that impairment is also occurring at the Lake Erie basin sub-population level.

Photo: U.S. Fish & Wildlife Service, James Leupold

4.3.5.1 Nitrates

Nitrates are nutrients and do not bioaccumulate. However, at higher concentrations they have been shown to cause effects in amphibians that are similar to those caused by toxic contaminants. Because less research and monitoring data is generally available for amphibian populations as a group, the mechanisms for the observed biological effects of nitrates are not as clearly defined as those for other organisms. A short summary of what is known is provided below.

A review by Rouse et al. (1999) evaluated the risk of direct and indirect effects of nitrate on amphibian populations. This review used a simple comparison of known environmental nitrate concentrations in North American waters to nitrate concentrations known to cause toxicity in a laboratory setting to amphibian larvae and other species that play an important role in amphibian ecology.

Lethal and sublethal effects in amphibians are detected in laboratory tests at nitrate concentrations between 2.5 and 385 mg/L (Table 4.9). Amphibian food sources such as insects and predators such as fish are also affected by elevated levels of ammonia and nitrate in surface waters (Rouse et al. 1999). This may have important implications for the survival of amphibian populations and the health of food webs in general.

Environmental concentrations of nitrate in surface waters in agricultural watersheds around Lake Erie ranged from 1 to 40 mg/L. Of 8000 water samples from rivers in the watersheds of Lake Erie and Lake St. Clair in the Canadian Great Lakes and in US states in the Lake Erie watershed 19.8% had nitrate levels above 3 mg/L. This concentration was known to cause physical and behavioral abnormalities in some amphibian species in the laboratory (Rouse et al. 1999). A total of 3.1% samples contained nitrate levels that would be high enough to kill tadpoles of native amphibian species in laboratory tests (Rouse et al. 1997).

4.4 Ecological Impairments

Ecological beneficial use impairments are intimately interconnected, and in Lake Erie include: degradation of fish, wildlife, phytoplankton and zooplankton populations; loss of fish habitat, loss of wildlife habitat; eutrophication or other undesirable algae; degradation of benthos; fish tumors or other deformities; and bird or animal deformities or reproduction problems. Therefore, the status of these beneficial use impairments needs to be integrated to develop a more comprehensive understanding of stressor impacts to the system as a whole. The results of beneficial use impairment assessments for fish tumors or other deformities, bird or animal deformities or reproduction problems, and benthic impairments caused by chemical contaminants are covered in detail in section 4.3, but are also mentioned in this section because dysfunction in the ecosystem is caused by contaminants as well as other stressors. Table 4.10 summarizes both the types of impairment and impairment conclusions for the noncontaminant related ecological impairments.

Table 4.9: The Toxicity of Nitrate to Amphibians (Rouse et al. 1999)

Species	Stage	Endpoint	Concentration of Nitrate (mg/L)
Bufo americanus	Tadpole	96h-LC50	13.6 & 39.3
Pseudacris triseriata	Tadpole	96h-LC50	17
Rana pipiens	Tadpole	96h-LC50	22.6
Rana clamitans	Tadpole	96h-LC50	32.4
Pseudacris triseriata	Tadpole	Developmental	2.5-10
Rana pipiens	Tadpole	Developmental	2.5-10
Rana clamitans	Tadpole	Developmental	2.5-10
Bufo bufo	Tadpole	96h-LC50	385
Bufo bufo	Tadpole	Developmental	9
Bufo bufo	Tadpole	Death	22.6
Litoria caerulea	Tadpole	Developmental	9
Litoria caerulea	Tadpole	Death	22.6
*Rana temoraria**	Adult	EC50-paper	3.6 g/m^2
Rana temoraria	Adult	EC50-soil	6.9 g/m^2

* Frogs were placed on moist paper or soil spread with ammonium nitrate granules
LC50=lethal concentration required to kill 50 percent of the test population within 96 hours
EC50=lethal concentration for 50% of the population

The ecological beneficial uses were assessed in relation to historical conditions, existing management goals and objectives, out-of-system references (where available), and recent concerns, as applicable. Impairments occur to all of the beneficial ecological uses of the lake.

To fully understand the causes of impairment as outlined below, it must be understood that population impairments are often a subset of habitat impairments. Therefore, this ecological use synthesis starts by addressing habitat to document the causes and extent of impairment. The underlying causes (stressors) of the habitat degradation are examined. Habitat impairment information is grouped by stressor because each stressor generally affected a broad range of habitat types.

Population information is organized by impairment results, rather than by stressors causing impairment, because population impairments integrate across trophic levels to the whole ecological community. One of the criteria for determining habitat impairment is inability to support healthy benthos, plankton, fish, and wildlife populations. So, when the status of these populations is summarized, lost and degraded habitat is one of the key causes of population impairment.

The key reasons for habitat impairment, called primary stressors, are hydrology changes associated with land use, nutrient and sediment loads, invasion of non-native species, and contaminants. All of these primary stressors are the result of human use of the Lake Erie environment. Due to the adverse impacts of primary stressors on the Lake Erie environment, some key secondary stressors have also emerged. For example, due to the irreversible loss of large areas of Carolinian forest habitat, black-crowned night herons and egrets are primarily restricted to breeding on the Lake Erie islands in the western basin. Here they compete for habitat with the booming double-crested cormorant population. The cormorant population is present because of protection from human disturbance and an abundant food supply of exotic pelagic fish (alewife, shad, smelt). The cormorant guano is killing the trees in which herons and egrets nest.

In this case, the primary stressor is changing land use that led to the loss of mainland habitat. The secondary stressor is the impact of the cormorant population on the island habitat that remains. Therefore, when examining causes of impairment and means of rehabilitation, it is important to understand the sequential interactions of stressors as well.

Table 4.10: Summary of Ecological Impairments

Impaired Use	Impairment Conclusions	Types of Impairment	Causes of Impairment
Degradation of Phytoplankton and Zooplankton Populations*	**Impaired** - entire *eastern basin*; lake effect zones of certain *western and central basin* tributaries	*PHYTOPLANKTON - eastern basin* - total standing crop and photosynthesis are below the potential set by P loading in the nearshore; Loss of keystone species; Loss of trophic transfer to *Diporeia* *ZOOPLANKTON - eastern basin* - loss of dominant cold-water species; *Eastern and west-central basins* - reduction in mean size points to potential impaired trophic transfer; *West central basin - Bythotrephes* acts as an energy sink	Zebra and quagga mussel grazing; High planktivory
Degradation of Fish Populations*	**Impaired** in *all basins* (species impaired vary by basin)	Unmet fish population objectives**; Loss of spawning/nursery area; loss of population diversity; rare, threatened, endangered and special concern species; reduced predatory function; Unnaturally high fish community instability; Inefficient use of food web energy	Habitat loss and degradation; Non-native invasive species; Loss of forage fish availability; Overexploitation; Loss of native stocks/species, particularly keystone predators
Loss of Fish Habitat*	**Impaired** in tributaries, shorelands, and nearshore of *all basins* (note - nearshore includes entire western basin area)	Unmet fish habitat objectives**; Loss of habitat diversity & integrity; Loss of spawning/nursery areas; barriers to migration; Changes in stream temperature, water quality, and hydrology; high turbidity; loss of aquatic vegetation; changes to benthic species composition; *western and central basin* lake effect zones - habitat loss and degradation	Destruction and draining of wetlands; Dams, dikes, dredging/ channel modifications, water taking; streambank/shoreline filling and hardening; sediment/ chemical contaminant/nutrient loadings; Navigation/recreational boating activities; exotics (carp, purple loosestrife, *Phragmites*) *Cladophora* fouling (eastern basin nearshore)
Degradation of Wildlife Populations	**Impaired** in *all basins* Detailed case studies are being prepared for 20 species or wildlife groups (birds, mammals, amphibians and reptiles) to illustrate the key impairment issues affecting the larger group of wildlife species that use the Lake Erie environment	Unmet wildlife population objectives**; Population fragmentation, isolation, and instability; loss or reduction in species indicative of quality habitat; loss of source populations; Rare, endangered, threatened, and special concern species; accelerated rates of parasitism/predation; Competition between wildlife/non-wildlife uses of a given habitat; changes to ground temperature and moisture conditions in forested areas; loss of travel lanes; loss of range/area-sensitive species (e.g. amphibians & reptiles, rails, bitterns, sedge wrens, bald eagle)	Fire suppression; logging; destruction and draining of wetlands; high water levels, storm surges; dredging/channel modifications, water taking, streambank/shoreline filling, hardening and backstopping; sediment/chemical contaminant/ nutrient loadings; navigation/ boating activities; non-native invasive species (zebra mussel, carp, purple loosestrife, *Phragmites,* garlic mustard, Eurasian milfoil, hybrid cattail, mute swan, gypsy moth, Dutch Elm disease, Chestnut blight)

Impaired Use	Impairment Conclusions	Types of Impairment	Causes of Impairment
Loss of Wildlife Habitat	**Impaired** in *all basins* 16 major habitat types were assessed. 13 were impaired in all Lake Erie jurisdictions where they occur (open lake, islands, sand beach/ cobble shore, sand dunes, submerged, floating and emergent macrophytes, wet meadow, shrub swamp, mesic prairie, upland marsh, mesic and swamp forests)	Unmet wildlife habitat objectives**; habitat fragmentation and loss of niches; loss of diversity and integrity; population demands exceed available habitat (e.g. colonial waders that use the Lake Erie Islands); loss of stopover habitat along migratory corridors (birds, butterflies, bats); loss of cover for protection from predation; loss of or accelerated succession patterns; loss of area available for habitat expansion; loss of buffer functions between one habitat type and another; loss or reduction in quantity/ quality of nesting/denning areas; loss or reduction in quantity/quality of food sources	Fire suppression; logging; destruction and draining of wetlands; high water levels, storm surges; dredging/channel modifications, water taking, streambank/shoreline filling, hardening and backstopping; sediment/chemical contaminant/ nutrient loadings; navigation/ boating activities; exotics (zebra mussel, carp, purple loosestrife, *Phragmites,* garlic mustard, Eurasian milfoil, hybrid cattail, mute swan, gypsy moth, Dutch Elm disease, Chestnut blight)
Degradation of Benthos	**Impaired.** *Eastern basin* **-** offshore waters; *Central basin* - tributary, shoreland, nearshore and offshore waters; *Western basin* - tributary, shorelands, offshore waters	Degraded benthic community (composition and interactions among components) compared to reference conditions; dominant species indicate degraded environment; Keystone species absent or nearly gone: **all basins* - unionid mussels, *Gammarus* amphipods; **east and central basins - Diporeia* amphipods; **east and western basins* - fingernail clams; **middle* of western basin - *Hexagenia* (mayflies); Unmet objectives for benthic density, biomass or productivity**; toxicity to benthic organisms (section 4.3.1); elevated incidence of deformities or other abnormalities (section 4.3.1); contaminant burden is high enough that predators may be at risk of bioaccumulating toxics (section 4.3.1)	Contaminated sediments, non-native invasive species or exotics (zebra mussel, round goby, etc.), loss and degradation of habitat particularly in wetlands
Eutrophication or Undesirable Algae*	**Impaired** - Maumee Bay, lake effect zones of Maumee/Ottawa Rivers, *western basin*; nearshore and river mouth areas of Canadian *eastern basin* Potentially impaired - lake effect zones of certain Ohio tributaries, *western and central basins*; Rondeau Bay and nearby nearshore and river mouth areas, Canadian *central basin*	Excessive *Cladophora* (see Degradation of Aesthetics impairment conclusions), degraded fish communities in lake effect zones of certain tributaries, P levels above Canadian guidelines in tributaries, Dreissenid grazing resulting in improved light penetration in nearshore zones	Phosphorus Non-native invasive species

More detailed technical information is available on-line at http://www.epa.gov/glnpo/lakeerie/buia/index.html
**See Section 4.1 for a discussion of existing objectives and their relationship to Lake Erie LaMP ecosystem objectives.

4.4.1 Habitat Impairments

4.4.1.1 Introduction

The IJC very broadly defined habitat as the "specific locations where physical, chemical and biological factors provide life support conditions for a given species." Specifically, the IJC indicated that "habitat impairment occurs when fish and/or wildlife management goals have not been met as a result of loss of fish or wildlife due to a perturbation" of the habitat. Management goals have been developed for birds - North American Waterfowl Management Plan (NAWMP), National Shorebird Plan, and Partners in Flight - Flight Plan, and fish - Lake Erie Fish Community Goals and Objectives. In addition, when the IJC developed listing criteria for determining benthic impairment, they included a recommendation that ecosystem health objectives be developed using benthic community structure. This recommendation has been implemented by a number of Lake Erie researchers (particularly for keystone species) and the resulting *objectives* have become widely accepted in scientific circles, even though they do not yet reside in any formal management plan. For other organisms, key indicator species and/or community structure were examined.

To assess the quality of the habitat in the Lake Erie basin, the basin was divided into 18 regions of similar physical, chemical and biological structure. The present evaluations were based not only on the ability of the present habitat to support fish, wildlife, plankton and benthic populations (ecological function) and on local and lakewide objectives as prescribed by the IJC, but also on historical records/out-of-system references, and recent concerns. Table 4.11 summarizes our present information linking stressors and habitats.

Loss of natural area to human use (i.e. agriculture, industry, housing) is an impairment in all Lake Erie basin upland habitat types, and extends shoreward to include wet meadows, emergent macrophytes, interdunal wetland and unconsolidated shore bluffs. So much of the original habitat has been lost that fragmentation of habitat and the small size of remaining habitat have impaired mesic forest, swamp forest, shrub swamp, mesic prairie, wet meadow, and wetland complexes. Other stressors are further degrading the remaining natural habitat.

4.4.1.2 The Habitat Continuum

Habitat degradation in the Lake Erie basin is due to a number of stressors, acting in concert. Even if the most critical stressor were alleviated, complete recovery would not occur. Remediation will likely require improvement in a number of areas. Table 4.11 summarizes our understanding of the relationship between stressors, habitat impairment, and impacts to populations of benthos, fish and wildlife. Stressors are listed vertically by category (altered hydrology, changing land use, and other) and the major habitat types assessed in the Lake Erie basin are listed horizontally. Where X is used, the applicable stressor affects that habitat for fish, benthos and/or wildlife. Where there is nothing in a cell, it means that the particular stressor does not significantly affect that particular habitat in the Lake Erie basin. In addition to integrating this information, the table is designed to provide a preliminary tool for developing an action agenda. Shore habitat definitions are presented in Table 4.12.

The 18 habitat types listed in Table 4.11 form a continuum of changing physical, chemical and biological structure along gradients of water/moisture, light penetration, and substrate type. In sheltered aquatic areas, habitat progresses from open water to submerged macrophytes, floating macrophytes, emergent macrophytes and then wet meadow and shrub swamp or mesic prairie as water depth and flooding decrease and light becomes more available. In exposed aquatic areas, the nearshore habitats progress from sand or cobble substrates below water to beaches, interdunal wetlands in the sheltered hollows behind the beach or fore-dunes, and sand dunes. These two suites of nearshore habitats absorb the wave energy during storm events, protecting the upland regions from the more severe flooding and erosion events that are present today in comparison with historical conditions. Degradation of the beach and wetland complexes has decreased their ability to absorb the force of storms and is considered a cause of impairment of the dunes, wet meadows, mesic prairie and forests. On land, the dunes and mesic prairie give way to mesic forest. In the uplands, swamp forest, marshes, bogs, fens and vernal ponds develop in depressions and kettles. A similar progression of habitats radiates out from the larger open water and marsh areas and sheltered regions of tributaries. The floodplains of the tributaries develop shrub swamp and swamp forest.

The interconnectedness of the habitats in the Lake Erie basin means that: 1) degradation in one habitat has consequences for adjacent or downstream habitats, and 2) stressors generally affect a range of similar or adjacent habitats across a gradient. Some stressors, such as contaminants and loss of habitat area, affect community function in a broad range of habitats. Because habitats are highly interconnected, many species do not spend their entire life cycle in one habitat. For example, many species of birds that are habitat specific during the nesting season utilize a completely different set of habitats during the migration periods and may winter in entirely different regions of the continent. Another example is northern pike that live among submerged macrophytes as adults, but breed in flood pools associated with tributaries. Their young live in the emergent vegetation. Turtles and snakes that live in marshes and swamps lay their eggs in nearby forest and beach ridges. To support intact fish and wildlife communities, it is important for the whole range of habitats to be present and naturally functional.

Tributaries provide an excellent example of the importance of the health, interdependence, and connectivity of adjacent habitats frequently emphasized in the beneficial use assessments (see Figure 4.1). Tributary flow regime (the magnitude, timing, duration, frequency, and rates of change of water movements within a watershed) is intimately connected with the watershed tablelands. Formerly, natural drainage patterns through wet forest and meadow habitat water retention areas controlled the amplitude and frequency of spring floods and maintained summer base flows. Cultural land use practices associated with settlement, deforestation, and agriculture increased drainage efficiency. The amplitude and frequency of spring flooding in basin tributaries increased, as well as the amount of physical energy entering the stream courses. Due to accelerated spring run-off with reduced groundwater recharge, summer base flows were reduced. The draw down of the water table for human use has reduced the flow of spring water to certain rivers in eastern Ontario. This has further reduced summer base flow in these systems and impaired the spawning reaches of cold-water anadromous fish, such as trout.

The damming of lake basin tributaries is almost universal in scope. Dams alter the connectivity of stream systems and are barriers to migrations and other ecological interactions. Dams with sediment trapping abilities alter the physical hydrology and sediment dynamics in downstream reaches. Floodplains provide periodic connectivity between stream channel habitats and those habitats in these aquatic/terrestrial transition zones. Native terrestrial and aquatic species that are dependent on floodplain habitats evolved in these unique systems under natural flow regime conditions. Floodplains also provide for retention and assimilation of sediments, nutrients, and contaminants that are carried in the stream flow. The loss of assimilation capacity in tributary floodplains and their associated wetland complexes affects

Table 4.11: Summary of the Stressors Affecting the Habitats in the Lake Erie Basin

Habitat Zone Stressor/Habitat Type	Aquatic Habitat			Shore Habitat		
	Open Water Offshore	Open Water Nearshore	Tributaries*	Islands	Sand Beaches Cobble Shore	Unconsolidated Shoreline
Altered Hydrology						
Altered groundwater - wells, logging			X			
High water levels - erosion, flooding		X		X	X	X
Lack of along shore sand movement		X			X	
Tributary flow		X	X			
Stream channelization		X	X		X	
Dams - sediment, water, barrier		X	X		X	
Draining			X			
Dredging	X	X	X		X	
Entrainment		X				
Heated effluent		X				
Changing Land Use						
Conversion to human use (e.g.farm)		X	X	X	X	X
Degradation of adjacent habitat		X	X		X	
Fire suppression						
Nutrient addition	X	X	X			
Increased sediment loads		X	X			
Hardening/development of shoreline		X	X	X	X	X
Backstopping/dikes		X	X		X	
Quarrying/mining/gas & oil wells	Possibly	X	X	X		
Logging			X			
Other						
Non-native invasive species	Quagga	Carp, Zebra	Carp	Dreissenids		Non-native plants
Contaminants	X	X	X			
Cormorants/Deer				X		
Loss of large mammals						
Direct human use of natural habitat (e.g. boating, hiking)		X	X	X	X	

*Tributary habitat includes floodplain forests and certain swamp forests.

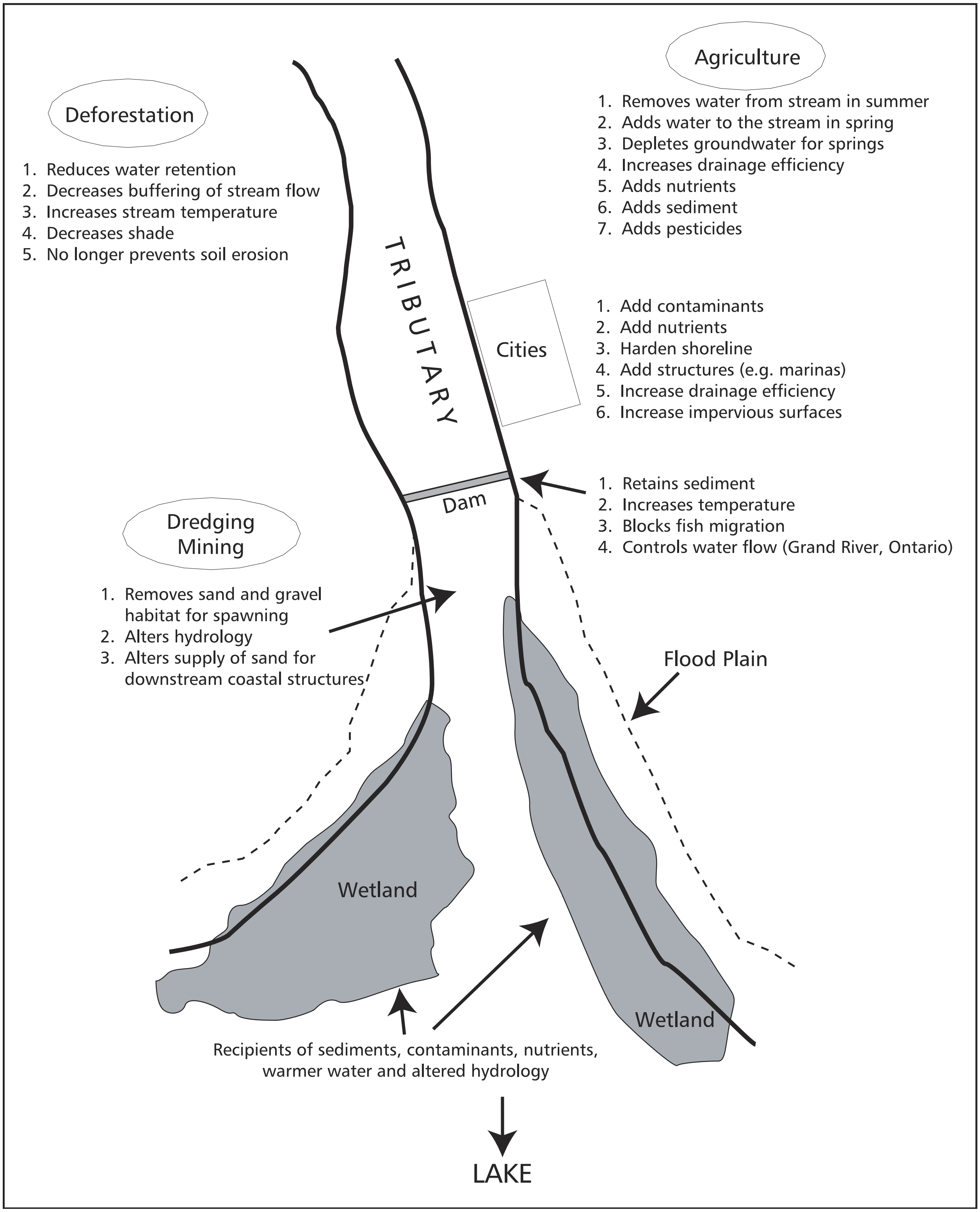
Habitat Zone Stressor/Habitat Type	**Shore Habitat**		**Nearshore Habitat**		
	Interdunal Wetland	Sand Dunes	Submerged Macrophytes	Floating Macrophytes	Emergent Macrophytes
Altered Hydrology					
Altered groundwater - wells, logging		X			X
High water levels - erosion, flooding	X	X	X	X	X
Lack of along shore sand movement	X	X			
Tributary flow			X	X	X
Stream channelization			X	X	X
Dams - sediment, water, barrier					
Draining	X	X	X	X	X
Dredging	X		X	X	X
Entrainment					
Heated effluent					
Changing Land Use					
Conversion to human use (e.g.farm)	X	X			X
Degradation of adjacent habitat	X	X	X	X	X
Fire suppression					X
Nutrient addition			X		
Increased sediment loads	X		X	X	X
Hardening/development of shoreline	X	X	X	X	X
Backstopping/dikes	X	X	X	X	X
Quarrying/mining/gas & oil wells					
Logging					
Other					
Non-native invasive species	Carp, Non-native plants	Non-native plants	Carp, Non-native plants, Mute swan	Non-native plants, Carp	Carp, Non-native plants
Contaminants					
Cormorants/Deer		X			
Loss of large mammals					
Direct human use of natural habitat (e.g. boating, hiking)	X	X		X	X

Habitat Zone Stressor/Habitat Type	**Upland Wetland**					**Uplands**	
	Wet Meadow	Mesic Prairie	Shrub Swamp	Bogs & Fens	Upland Marsh	Mesic Forest	Swamp Forest
Altered Hydrology							
Altered groundwater - wells, logging	X	X	X	X	X	X	X
High water levels - erosion, flooding	X		X				X
Lack of along shore sand movement							
Tributary flow			X				X
Stream channelization	X	X	X	X			X
Dams - sediment, water, barrier							
Draining	X	X	X	X	X		X
Dredging	X				X		X
Entrainment							
Heated effluent							
Changing Land Use							
Conversion to human use (e.g.farm)	X	X	X	X	X	X	X
Degradation of adjacent habitat	X	X	X	X	X	X	X
Fire suppression	X	X	X	X	X	X	X
Nutrient addition				X	X		
Increased sediment loads	X		X	X	X		X
Hardening/development of shoreline	X		X				
Backstopping/dikes	X		X				X
Quarrying/mining/gas & oil wells				X		X	
Logging						X	X
Other							
Non-native invasive species	Non-native plants	Non-native plants	Carp, Non-native plants	Non-native plants	Carp, Non-native plants	Non-native plants	Non-native plants
Contaminants							
Cormorants/Deer	X	X	X	X	Deer	Deer	Cormorant, Deer
Loss of large mammals	X	X					
Direct human use of natural habitat (e.g. boating, hiking)					X	X	X

Table 4.12: Definitions for Lake Erie Habitats

Habitat	Definition
Islands	With the exception of Mohawk Island, primarily limited to the western basin of Lake Erie. Permanent islands with rock bound shores below dolomite or limestone cliffs. Due to the moderating effects of surrounding lake waters, the climate of the islands has a greater range in annual mean temperature, less precipitation, smaller range of daily temperature, and a longer frost-free season then the neighboring mainland.
Sand Beaches/ Cobble Shore	Temporary open shorelands controlled by shifting sands and fluctuating water levels. Composed of rock fragments ranging from fine sand to large boulders. Devoid of or have minimal vegetation.
Unconsolidated Shoreline	Restricted to the eastern and central basins. Bluffs consisting of a rock or clay base with a thin topsoil layer along the top.
Interdunal Wetlands	An integral component of the marsh complex and the wetlands closest to the lake proper. Formed behind the active shoreline when lake levels have been stable enough to provide elevated dune areas. Wet pockets behind the foredunes or beaches and lakeward of the inner dunes or ridges.
Sand Dunes	Formed by deposits of sand and gravel along the lakeshore in areas that are no longer under the effect of the active wave zone. Three communities are found in the Lake Erie basin: a) grassland dune complexes; b) wooded beach ridge, and c) the sand barrens found on ancient beach ridges.
Submerged Macrophytes	Occurs in marsh and open lake settings. Characterized by pondweeds, milfoils, coontail, wild celery, and bladderworts that depend on water pressure/buoyancy for support of their thin, pliable stems.
Floating Macrophytes	A transition from open water habitat to emergent marsh vegetation. Occurs in shallow, protected water within streams and coastal marshes. Dominated by rooted plants with floating leaves such as water lily, spatterdock, water-lotus, water smartweed, and floating-leaved pondweeds.
Emergent Macrophytes	Consists of 2 community associations: a) robust emergents (cattail and hardstem bulrush) occurring lakeward, and b) narrow-leafed emergents (bulrushes, smartweeds, millets, burreed, rice-cutgrass, wild rice, etc.) occurring shoreward. Survive best in stable water levels, but can tolerate fluctuations for short periods.
Wet Meadow	Occurs as a band of vegetation in a transition zone above normal water levels. Soil is moist and may be inundated for a period of time sufficient to reduce the establishment of woody vegetation. Dominant species include bluejoint grass, northern reed grass, slough grass and sedges.
Mesic Prairie	A series of tall and short-grass prairie complexes governed by water availability. Historically fire prevented this habitat from succeeding to wooded habitat.
Shrub Swamp	Distinct from marsh in being dominated by woody vegetation (pussy and sandbar willow, swamp rose, meadow-sweet, silky dogwood, and buttonbush). Generally occur in glacial kettles or around the margins of lakes or marshes. Highly dependent on natural hydrology.
Bogs and Fens	Bogs are acidic, peat-accumulating, wetlands with as many as 5 distinct vegetative zones. Fens are also peat-accumulating wetlands, where mineral rich (alkaline) spring water comes to the surface, and typically have a marl zone dominated by sedges. Generally bogs and fens are successional habitats that naturally advance to upland habitats in the absence of intervention.
Upland Marsh	Found in low areas of the upland landscape in kettle lakes or pothole-type wetlands. All portions of the coastal wetland complex can also occur in upland marshes.
Mesic Forest	Mature stage of the deciduous forest consisting of oak-hickory and beech-maple communities. Historically, fire was a key controlling factor of this habitat type.
Swamp Forest	Consists of floodplain forest and deciduous swamp forest. Floodplain forests occur with stream and river channels that are at least periodically flooded, and common species include silver maple, cottonwood, sycamore, black willow, green ash, box elder, and Ohio buckeye. The typical dominant species of swamp forest include red and silver maple, black ash, swamp white and pin oaks.

Figure 4.1: Summary of impacts on tributaries from adjacent habitats and the impact of tributaries on downstream habitats



environments in interdependent nearshore zones (e.g. regions used by larval fish) and diverts the water, nutrients and sediments into the remaining wetlands, causing degradation of the wetland complex and nearshore regions of the lake.

Tributaries and their watersheds naturally provide a certain level of nutrients and sediments to the swamp forest in the floodplain, the lake and the wetland complexes. When the natural pattern of sediment and nutrient flow is altered, problems develop. Dams are a major reason for fish habitat impairments on tributaries. Dams trap the heavy sediments such as sand that are needed downstream to maintain beaches, sand bars and coarse-grained sublittoral habitats. Fine-grained sediments, from the erosion of topsoil, are suspended in the water and are released by dams. A certain amount of this material is needed by downstream vegetation as a source of minerals and nutrients. Too much can smother the vegetation through siltation and lead to eutrophic conditions. Dams not only trap sediment and water, altering both the upstream and down stream habitats, but also isolate populations and block the migration of anadromous fish to upstream spawning grounds. Dams are a major source of impairments on tributaries.

With deforestation the lack of shade, both along the river edge and in the fields that drain into the river, allows the river water to reach warmer temperatures that can be detrimental both to the biota in the river as well as in the downstream wetlands. Expected increases in temperature with climate warming will only heighten this problem. Thus tributaries are affected by activities in adjacent land-based habitats, and effects typically move downstream to the swamp forest, wetland complexes, sand beaches, littoral regions, and finally to the open lake.

Two general impairments are related to the transference of impacts from one habitat to another. First, the shoreline habitats each protect the next inland habitat from storm events. They were each considered impaired due to the impairment of adjacent habitats. Second, modification of the hydrologic regime or water table in one habitat alters the hydrologic regime in all neighboring habitats in a cascading manner. Flowing water forms a geological continuum with a progression of habitat types that develop along the gradient in moisture. Changes in hydrology due to human activities (logging, clearing land, wells, draining, backstopping) have caused impairments in all terrestrial and marginal habitats.

4.4.1.3 Stressors of Aquatic and Terrestrial Habitats

Aquatic Habitats

High Water Levels, Backstopping

The development and maintenance of the nearshore water-based habitats is a dynamic process controlled by along-shore sediment (sand) load in currents, the degree of shoreline indentation and structure, water levels and storms. Historically, the nearshore habitats moved inland or lakeward in response to changes in water levels. One of the major stressors on nearshore habitats (wetlands, sand/cobble beaches, unconsolidated shore bluffs, interdunal wetlands and sand dunes) in the past 30 years has been high water levels, particularly when coupled with shoreline hardening or development. The shoreline habitats have not been free to move inland, but rather are trapped in a narrow area between the water and man-made structures. When shoreline habitats are trapped, they are much more susceptible to the impacts of strong storms that not only severely alter their physical features, but also flush out detrital and planktonic matter into the nearshore margins faster and in higher amounts than what normally occurs from the marshes.

Sand bars and wide stretches of beach and/or submergent vegetation normally dissipate the force of these storms. Dikes were built or improved in the 1970s to protect the remaining marshes along the south shore of the western basin, which otherwise would have been lost (Boggy Bottoms, Deer Park Refuge; Mallard, North Bay, West Bay, and Green Creek Clubs; Metzger, Magee, Navarre, Toussaint, Trenchard's, Rusk, Moxley, and Erie Marshes; Ottawa and Winous Point Shooting Clubs; Little Portage, Toussaint, Pickerel Creek, Willow Point, Pipe Creek, Pointe Mouillee, Cedar Point and Ottawa National Wildlife Refuges).

The vast biodiversity of the wetland wildlife communities are dependent on a vegetated wetland complex. Dikes to protect the remaining wetlands from the combination of high lake levels and backstopping (to protect human use areas from the lake), storm surges, and non-native invasive species (i.e. carp, purple loosestrife, and reed-canary grass), have been the only means of survival for these diverse communities.

While isolation of these wetlands from the lake has provided the sole remaining habitat for many wildlife, invertebrates and bird species, it has also impaired their use as fish habitat. Many fish species utilize wetlands at some point in their life. To fully rehabilitate the fish community in Lake Erie, coastal wetlands must be re-connected to the lake. An ongoing experiment is underway at the Metzger Marsh where a dike has been engineered to allow limited entry and exit to selected fish close to natural cycles in water elevation, while still protecting the marsh from storms and carp.

High water levels also promote more extensive erosion of bluffs and beaches. In the past, the resulting sand was carried along shore and used to maintain and build up new beaches, underwater sandbars and shoals, and dunes. Breakwaters and other structures built out into the water, as well as the armoring of shorelines with rip-rap and dikes, have altered the intensity and paths of water currents redirecting much of this sediment load to deeper waters. The beaches have become narrower and more vulnerable to storms and seiches. These changes have decreased the feeding, nesting and resting opportunities for shore and wetland birds and wildlife, and increased the likelihood of their disturbance by people and by domestic and wild animals.

Turbidity and Nutrients

Forestry, agriculture, sewage disposal and combined sewer overflows have caused unnaturally high inputs of nutrients and sediments to the lake in the past. Remedial actions have greatly reduced these inputs and their effects on the lake. Eutrophication is no longer considered a widespread issue in the open waters of the lake: phosphorus and chlorophyll *a* levels are close to objectives. Due to periodic anoxia, open waters of the central basin are dominated by tubificid benthos, an indication of impairment. Elevated phosphorus levels, high turbidity, degraded benthic communities (although improved over those in the 1960s), and the abundance of omnivorous fish indicate that tributary mouths are still degraded. Where nutrients have been measured excessive phosphorus remains a localized problem. Along with nutrients, sediment loading is still a problem in numerous tributaries particularly in the western half of the lake. The offshore waters of the western basin and south shore of the central basin still show residual effects of eutrophication. Benthic communities in these regions are still impaired based on the high densities of tubificid worms, although their densities have been declining through the 1990s. The recolonization of the western offshore regions by *Hexagenia* starting in 1992 is thought to be due to improved oxygen conditions and decreased contaminant concentrations in the sediment throughout much of the basin.

Fine sediments have fouled the gravel and coarse substrates in the tributaries, shoreland, and nearshore environments reducing their suitability and use as spawning and feeding areas for fish or habitat for invertebrates. Many river spawning stocks were lost due to a combination of fouled spawning shoals and dams, e.g. northern pike, sauger, muskellunge, whitefish, sturgeon and walleye. Populations in the open lake are now maintained largely by lake spawning stocks. Rehabilitation of streams is allowing the recovery of some walleye river stocks and development of naturalized populations of rainbow trout. Pacific salmon (coho and chinook) are a minor component of stream spawners.

Improvements in water clarity during the 1990s can be attributed principally to the high filtering capacity of dreissenid mussels that invaded the lake in the late 1980s. Their impact has been particularly strong in nearshore regions and has allowed the redevelopment of submerged macrophyte beds. Submerged macrophytes in the open lake are not considered impaired. This habitat type is still considered impaired in the tributaries and wetlands due to loss of area (e.g. insufficient area to support wildlife and fish needs), and invasion of non-native invasive plant species, but is definitely improving.

Contaminants

Contaminants, which enter the aquatic system through run off from the land, direct disposal and atmospheric deposition, presently degrade areas in the open lake, nearshore and tributaries, particularly in the western basin. Contaminant levels are sufficiently high in some regions of the lake that impacts have been observed in both the highest trophic levels (bald eagles, herring gulls, cormorants, and common tern) and the lower trophic levels (benthic invertebrates). Sediment contamination has been listed as an impairment to benthos in the mouths of the Buffalo, Niagara, Grand, Black, Cuyahoga, Ashtabula, Ottawa, and Maumee Rivers and Swan Creek. Degraded benthic communities with higher than normal levels of mouthpart abnormalities (a measure of toxic impact) have been found in the nearshore regions off the Detroit and Maumee Rivers. Adult *Hexagenia* collected from western basin nearshore regions had higher contaminant burdens than those offshore, further suggesting that nearshore environments have contaminant problems.

Contaminants were considered one of the causes for the loss of *Hexagenia* from the majority of the lake in the mid-1950s. Although the *Hexagenia* population has made a remarkable recovery, particularly in the western basin, starting in the early 1990s its densities remain low through the central section of the basin. Contaminants are hypothesized to be the cause, although dissolved oxygen levels and sediment type are also critical to successful *Hexagenia* reproduction. *Hexagenia* larvae from the region of Middle Sister Island had high burdens of organochlorine compounds and PAHs.

Non-native Invasive Species

Carp were introduced in the last century and are the most physically destructive of the wetland exotics. They root through soft sediments and macrophyte beds while feeding, resuspending sediments and disrupting stabilizing root systems in the process. Their activities magnify the nearshore sediment and turbidity impacts and reintroduce nutrients and contaminants buried in the sediments to the water column.

Eurasian milfoil has invaded submerged macrophyte beds, while *Phragmites*, purple loosestrife, reed-canary grass and hybrid-cattail have invaded the emergent wetland habitats. These invasive species cause impairments because many grow as monocultures that are not suitable for use by native species, reduce habitat complexity and biodiversity, and are less nutritious for the native birds and wildlife. They are also more vulnerable to disease and other pests, as well as disturbance from fire and storms that would result in catastrophic loss of cover for all species.

Perhaps the most obvious and most significant non-native invasive species in Lake Erie are the two dreissenid mussels, the zebra and the quagga mussel. Apart from the effects of their filtering activity on water clarity that was mentioned earlier, their physical presence is altering the nature of hard and soft substrates in Lake Erie.

Terrestrial Habitats

The main causes of impairment in the terrestrial habitats were loss of habitat area, fragmentation, altered hydrology, logging, the invasion of non-native plant species, contaminants, and sedimentation of upland bogs, fens, marshes, and swamps. Logging has impaired the mesic and swamp forests. Removal of the largest (dominant) trees returns the forest to a lower successional state, decreases biodiversity of the entire system, removes food and nest/den sites, and opens up the canopy. Some of the losses of large trees with nesting cavities have been mitigated through nest box programs for such species as flying squirrels, wood ducks, bluebirds, and prothonotary warblers.

More sunlight can enter the forest, which increases the temperature of the leaf litter and dries the forest floor reducing the amount of wet habitat needed by the associated invertebrate fauna and amphibians. Non-native plants have invaded and often form monocultures through the forest. They include garlic mustard, Japanese knotweed, dame's rocket, buckthorn and, in moister areas, *Phragmites*, purple loosestrife and reed-canary grass. The impairments they cause are: insufficient area to support wildlife populations; loss of plant biodiversity in the habitat; loss of habitat complexity; and decreases in nutritional food sources for wildlife.

4.4.2 Fish, Wildlife, Benthos and Plankton Community Impairments

Many species or groups of animals living in the Lake Erie basin were found to be impaired. Impairments were determined on a number of bases: a) population objectives set for key fish, wildlife and benthic species which integrate community function (e.g. mayfly-*Hexagenia*) or represent important functional groups (e.g. diving ducks, top predators etc.), b) ecological function, c) historical records, and d) recent concerns. These translate into impairments in biodiversity, community stability, and food-web structure and function. The causes of these impairments were associated with altered or lost habitat, the invasion of non-native species, human disturbance, and contaminants (Table 4.11).

Contaminant impairment of wildlife was noted for the benthic community, benthic-feeding fish (tumors), fish eating birds, mudpuppies in tributaries and possibly for diving birds feeding on dreissenids. Impairments due specifically to contaminants are discussed in Section 4.3. The following sections examine impairments to biodiversity, community stability and food web structure and function, integrating effects across the different trophic levels where possible.

4.4.2.1 Biodiversity and Endangered Species

Biodiversity refers to the number of species supported by a self-sustaining community. Over time, biodiversity normally declines as a community/habitat becomes severely degraded because native species are often depressed or lost. In Lake Erie, habitat loss and degradation, human disturbance, commercial fishing, the introduction of non-native invasive species and contaminants have affected biodiversity.

Thirty-four species of fish have been given the status of rare, threatened, endangered, species of concern or extinct in Lake Erie. Some of these were dominant members of the historical fish communities. A large number of the dominant species in the Lake Erie aquatic community are now non-natives: smelt, alewife, gizzard shad, round gobies, white perch, rainbow trout, pacific salmonids, dreissenid mussels, *Echinogammarus*, *Cercopagis* and *Bythotrephes*. As these non-native species became dominant, the biodiversity of the historical fish, benthic, and plankton communities decreased. Smelt are linked to the decline of blue pike, lake herring, the large calanoid, *Limnocalanus*, the marked decrease in *Mysis,* and to the near demise of lake whitefish. The fish species mentioned above had been strongly affected by overfishing and habitat degradation prior to the arrival of the non-native smelt in the lake. Alewife, smelt and gobies are implicated in the loss of spoonhead, slimy and deepwater sculpins. Recent evidence suggests that contaminants, in particular 2,3,7,8-tetrachlorodibenzo-p-dioxin, may have been responsible for the final loss of lake trout from Lake Ontario, although the role of thiamine deficiency and the resultant early mortality syndrome (EMS) in larval fish cannot be ruled out. This opens the question of the possible roles of contaminants and diet in the loss of lake trout and other species from other Great Lakes. Dreissenids have eliminated the unionid and sphaeriid clams from all but a few

refuges in the coastal wetlands, and are hypothesized to be indirectly responsible for the loss of *Diporeia* from the eastern basin. *Echinogammarus* has replaced *Gammarus fasciatus,* itself an exotic, in many regions.

Wildlife species using wetlands for breeding habitats or as important migration stopover habitats make up the majority of rare, threatened, endangered, species of concern, or extinct species within the basin. For one jurisdiction over 80% of the listed birds (43 species), 40% of the listed mammals (2 species), and half of the listed reptiles (8 species) use the wetland or terrestrial habitats of the Lake Erie basin. Mammals such as snowshoe hare, rice rat, porcupine, timber wolf, marten, fisher, mountain lion, lynx, elk, and bison have all been extirpated or extremely reduced in range and/or population in the Lake Erie basin. For many of these species, rehabilitation cannot be an option. Habitat diversity is so severely reduced or altered in most wetland and terrestrial habitats, coupled with negative impacts of exotic plants on native vegetation, that diversity of the plant community has changed, which in turn has reduced the potential diversity of the wildlife community.

4.4.2.2 Community Stability

Open Lake

The fish community is considered unstable for a number of reasons: loss of critical habitat; loss of stabilizing effect of top predators; overwintering mortality of non-native species (alewife, shad); competition between native and non-native species; and inefficient transfer of energy through the food web. The loss or degradation of critical spawning/nursery habitat has made reproductive success less predictable and leads to reductions and variability in year class strength of most species. The LaMP has yet to assess reproductive problems in fish. When this assessment is conducted it will address the potential for contaminant impacts on community stability through effects on reproduction. As mentioned in section 4.4.2.1, recent evidence suggests that 2,3,7,8-tetrachlorodibenzo-p-dioxin may have been responsible for the final loss of lake trout from Lake Ontario. This opens the question of the possible role of contaminants in the loss of species from other Great Lakes and in the present reproductive function. Given that contaminants are: a) causing problems with benthos and top predators, b) at high enough levels to cause fish consumption advisories, and c) associated with tumors in brown bullheads, it would not be surprising if they were affecting the productive capacity of some fish populations.

Native stocks of the historical keystone predators (walleye, sauger, blue pike, northern pike, muskellunge) in cool-water habitats were extirpated or markedly reduced during the period from 1930 to 1972. These species were responsible for maintaining the structure and stability of the fish and lower invertebrate communities. Walleye populations recovered through the 1980s. In recent years, walleye distributions (move to deeper waters) have changed as transparency has increased, reducing the community-structuring role of this species. Blue pike would normally occupy this habitat, but have been extirpated from Lake Erie and are now biologically extinct. Northern pike and muskellunge are still rare in many regions, leaving some nearshore areas without strong piscivore structuring. Smallmouth bass provide this function in areas of rock substrate.

Lake trout are maintained by stocking and thus their predatory function is not impaired (their reproduction function, however, is impaired). Fisheries managers are trying to maintain the predatory function in the lake through maintaining native walleye stocks, by stocking lake trout, and by controlling sea lamprey populations. The sea lamprey is a non-native species that, as an adult, is parasitic on larger fish. Sea lamprey control was introduced to allow lake trout to reach sexual maturity, thereby making natural reproduction and self-sustaining populations possible. If the sea lamprey populations are not controlled they can: a) decimate the populations of larger fish, b) prevent lake trout rehabilitation, c) reduce the surplus fish for sport and commercial fisheries, and d) further decrease predator function and energy flow in the lake.

Sea lamprey control provides an excellent example of the potential conflicts involved in managing and trying to restore degraded systems. TFM is applied to tributaries to control the populations of juvenile sea lamprey, but it also kills other species of lamprey, mudpuppies, sculpin, and some invertebrates. Control of sea lamprey is imperative to the health of the fish community. Therefore, alternate strategies of sea lamprey control are presently being investigated by the Great Lakes Fishery Commission to reduce the use of TFM. Between 1990 and 1999, TFM use has been reduced by 39% Great Lakes wide and by 70% in the Lake Erie basin.

The non-native planktivorous fish, alewife and shad, are not well adapted to winter conditions in Lake Erie and often suffer overwintering mortality. The extent of that mortality is dependent on the severity of the winter, which is variable. Native fishes are better adapted to conditions in Lake Erie and are less susceptible to overwintering mortality. Therefore, the population size of native species is less variable and would provide a more stable food source to top predators than that of non-native species. Alewife and shad can outcompete native planktivores, and together with smelt are the dominant planktivores in the lake. With these species as dominants, the stability of the fish community has been decreased. The inefficient transfer of energy through the aquatic food web is discussed in section 4.4.2.3.

The benthic fish community is changing rapidly with the introduction of dreissenids that have altered benthic community structure and productivity, and of gobies that feed effectively on dreissenids and displace native sculpins. This community is not yet stable.

Photo: U.S. EPA Great Lakes National Program Office

Fish BUIA Update (from LaMP 2002)

The major point from the 1998 fish habitat BUIA was that the fish community was unstable due to loss of habitat, loss of top fish predator stocks, negative impacts of non-native invasive species and inefficient flow of energy through the food web. These factors continue to create instability in the Lake Erie fish community.

Since 2000, round gobies have spread throughout Lake Erie and have increased in abundance. They are now among the most abundant fish species on rocky substrates, feeding on a variety of organisms ranging from plankton to zebra mussels and other benthic invertebrates to fish eggs. They also have become a major prey of essentially all benthic fish predators, including smallmouth bass, yellow perch, walleye, and freshwater drum. In July 2001, the first tubenose goby was captured in western Lake Erie. Given the St. Clair River experience (where both tubenose and round gobies were initially found but round gobies eventually dominated), it is anticipated that tubenose gobies will not substantially add to the impacts of the round goby.

Walleye stocks should improve in the near future as Lake Erie's five fisheries management agencies support a Coordinated Percid Management Strategy, which will significantly reduce fishing mortality on walleye through 2003. The strategy also allows for the further development of adaptive fishery management on an interagency level. Strong walleye hatches in 1999 and 2001 should bolster the adult stocks in coming years with improved survival rates that result from reduced fishing. Yellow perch stocks should also benefit from the Coordinated Percid Management Strategy.

A five-year fisheries restoration program has been initiated by Ontario for eastern Lake Erie. In cooperation with the New York State Department of Environmental Conservation, Ontario is establishing regulations for conservative harvest, initiating a major stock assessment program, and implementing a program of fisheries inventory and habitat assessment for nearshore waters and lake-affected zones of rivers.

Positive signs in the western basin fish community are that white bass stocks appear to be increasing in abundance and prey fish populations have recovered from low levels during the mid-1980s. Increased populations of mayflies have increased the forage base for many fish species, including yellow perch. The silver chub, a benthic-feeding high-energy food source for other fish, is reappearing in abundant numbers. The silver chub practically disappeared from the lake simultaneously with the catastrophic decline of the mayfly in the early 1950s (Troutman, 1981). Coincidently, silver chubs feed on zebra mussels. Trout-perch, another benthic species that declined dramatically in the 1950s, is also making a comeback. These changes suggest that the historic benthic-feeding community in Lake Erie is beginning to recover (Thoma, personal communication).

Terrestrial Communities

In terrestrial communities, loss of habitat, contaminants and human interference have resulted in degraded community structure, a loss of predatory function and thus decreased community stability. Fragmentation of habitat and the small size of the remaining habitat impair wildlife in mesic forest, swamp forest, shrub swamp, mesic prairie, wet meadow and wetland complexes. The loss of habitat has altered community structure and increased the intensity of the interactions (competition, predation) within the remaining habitat. The small habitat areas remaining often cannot support animals that require large territories, such as eagles from the beach ridges along the south shore of Lake Erie or bison that once inhabited the mesic prairie. Species also become concentrated in small habitats and are then more easily located and vulnerable to predators and parasites. Fragmentation of habitat is also a serious problem. It particularly affects smaller, less mobile creatures, such as amphibians, reptiles and insects. When habitats are fragmented, little or no migration occurs between isolated parts of the same habitat type. The resultant small, isolated populations are more susceptible to extirpation. Frogs and salamanders are impaired in interdunal wetlands, wet meadows, shrub swamps, upland marshes and swamp forests partly for this reason. Increased probability of extirpation, predation and parasitism, limited gene pools, and lack of top predators or larger mammals all result in decreased community stability.

The large deer population, loss of bald eagles from the system, small populations of coyote and the extirpation of carnivores such as wolves reflect a loss of top predators in the terrestrial as well as the aquatic community. The impact of range expanding species, such as the cormorant, also suggests a decline in community stability. Several bird populations have expanded greatly and are negatively impacting other species or groups.

The decline in mainland habitat of colonial water birds is pushing black-crowned night herons and egrets into competition with cormorants, which arrived in the Lake Erie basin earlier this century. The breeding population of cormorants in the Lake Erie basin is restricted to the islands in the western basin. The population is expanding and their guano has the potential to kill the trees in which they nest. The loss of mainland habitat is restricting black-crowned night heron and egret breeding to these same islands and trees. This shrinking habitat base raises long-term concerns for the future of these species. Cormorants can nest on the ground, but egret and heron require trees.

Increasing ring-billed gull populations have displaced common terns from historic nesting sites on beaches, islands, and dune areas and result in increased predation on remaining nesting colonies. This is considered an impairment because the population levels of ring-billed gulls are elevated above historical levels, likely due to the additional sources of food provided by agriculture and human garbage. The piping plover is also impaired from increased ring-billed gull populations and other nest predators such as raccoons and skunks. Human disturbance has been a leading cause of extirpation of breeding piping plovers from the basin.

Black ducks prefer bog and fen type environments for breeding. Their population is impaired because it is below the objectives set by NAWMP. The recovery of black ducks is hampered by the large populations of mallard which outcompete them in the more open environment created by the altered land uses of the basin. Marsh management creates habitat more favorable for mallard breeding than black duck breeding. Bog and fen habitats cannot be rapidly created or restored for short-term recovery of black ducks.

Prothonotary warblers, which were considered as representative of the needs of a bird/amphibian complex, are impaired for the most part by habitat changes. However, their existence is jeopardized further by competition with exotic species (European starling, house sparrow) for nest sites and by nest parasitism by cowbirds.

On the positive side, bald eagle populations are increasing and expanding into new territories to nest. Colonies of great blue herons have been established in a number of tributaries in the U.S., and it is common to see the magnificent birds feeding in many shallow water habitats.

4.4.2.3 Altered Food Web Structure and Function

Aquatic Habitats (from LaMP 2000)

Dreissenids have radically changed the food web and in so doing are responsible for impairments to the benthos, plankton and fish communities. The high filtering capacity of dreissenids has probably impaired the phytoplankton community by decreasing phytoplankton biomass and primary productivity in nearshore regions of the eastern basin. This has translated into reduced zooplankton production in those regions and poor recruitment of young-of-the-year fish. Offshore in the eastern basin, dreissenids may be responsible for the decline in diatom species richness and biomass in the spring. An alternate hypothesis is that UVB radiation is responsible. The decline in diatoms is hypothesized to be responsible for the loss of *Diporeia* (benthic impairment), an important food source for fish (whitefish, young lake trout, and smelt) in the hypolimnion.

Dreissenids have also caused the loss of unionid mussels, sphaeriid clams and a shift of the offshore benthic community away from grazing and predacious invertebrates toward oligochaete worms. This new community is less able to support the historic fish community. Loss of *Diporeia* offshore intensified the predation of smelt on mysids and zooplankton. Strong predation on zooplankton by alewife and smelt has resulted in zooplankton communities composed of small species and in lower total zooplankton production.

The addition of *Bythotrephes*, a predatory zooplankter, has inserted another trophic level between herbivorous cladocerans and fish. *Cercopagis*, another predatory zooplankter, arrived in the last several years. This also decreases the efficiency of energy flow up the food web. The abundance of *Bythotrephes* in this planktivore-dominated system further suggests that *Bythotrephes* may be an energy sink. The zooplankton community in the eastern basin is not transferring energy to fish as efficiently as it might. Thus, in total, the food resources of fish in the eastern basin have been reduced. This food web disruption of the pelagia of the eastern basin is an impairment of the fish community as fish community goals and objectives for harvestable surplus fish cannot be met.

In addition to altering the food-base of the pelagic fish community in the eastern basin, dreissenid impacts on water clarity have affected the efficient use of this food by the fish community. The increased transparency of the water column has displaced the principal predator, walleye, from much of the habitat. The smelt population in the eastern basin is in poor condition. There is no longer efficient transfer of energy to a top predator. Thus, the surface waters of the eastern basin are impaired due to lack of a strong predator species that can utilize the habitat vacated by walleye. The food-web disruption of the pelagia due to dreissenids has been moving into the central basin. In the eastern and central basins, the decrease in smelt and rapid increase in gobies, which feed on dreissenids, is expected to affect predator feeding patterns and availability of predators to the fishery.


Photo: Mike Weimer, U.S. Fish & Wildlife Service

In the western basin, *Microcystis* blooms have developed in association with dreissenids. The cause of these blooms is being investigated and is hypothesized to be due to nutrient release by dreissenids. *Microcystis* is a blue-green alga that produces toxins and is not readily consumed by other organisms. After many years of being absent, blooms have appeared sporadically for a number of recent years over a wide area, and are therefore likely a signal of impairment.

Dreissenid impacts have also benefited some groups of plants and animals. Increased water clarity has allowed the expansion of submerged macrophyte beds, and therefore the expansion of northern pike, muskellunge and sturgeon populations associated with this habitat. These species are still rare in Lake Erie. The increased macrophyte beds should help protect the emergent marshlands and provide new habitat for macroinvertebrates. Lake Erie is a critical staging area for diving ducks, such as mergansers, redheads, canvasbacks, and greater and lesser scaup, which use this habitat. Vegetation eaters, such as redhead and canvasback ducks, are showing wider use of sites. Mollusc eaters, such as scaup, are remaining for extended periods to feed on dreissenids. Mergansers are able to more efficiently feed on their small fish prey in the clearer water. Diving ducks, except for scaup, are meeting North American Waterfowl Management Plan (NAWMP) objectives and are not impaired.

Terrestrial Habitats

In the terrestrial communities, the invasion of non-native plants and harvesting of mast-bearing trees has altered the base of the food webs. Non-native plants, such as garlic mustard, Japanese knotweed, dames rocket, buckthorn and, in moister areas, *Phragmites*, purple loosestrife and reed-canary grass, often form monocultures thereby reducing the variety of foods and are often less nutritious than the native plants.

Direct human disturbance has also reached the point of impairing the wildlife population thereby affecting community and food web functions. Through recreational use of habitats, people and their pets have negatively impacted these sentinel groups/species: diving ducks, the common tern, piping plover, and other shorebirds, bald eagles, black terns, snapping turtles and eastern spiny softshell turtle. In some instances, animals are scared from roosting or feeding areas, which incurs an energetic cost. In other instances, the reproduction of the organism is affected, which incurs a population cost. Human disturbance was noted as a factor affecting wildlife in a number of different habitat types: open water, islands, beaches, bluff, interdunal wetlands, mesic prairie, mesic forests and swamp forests. Only in submerged and floating macrophyte beds, beaches, and sand dunes was human recreational activity impairing the habitat, per se.

4.5 References

Culver, David A. 1999. Toxicity, Ecological Impact, Monitoring, Causes and Public Awareness of Microcystis Blooms in Lake Erie. Report to the Lake Erie Commission.

Gilderhus, P.A. and B.G.H Johnson. 1980. Effects of Sea Lamprey (Petromyzon marinus) Control in the Great Lakes on Aquatic Plants, Invertebrates, and Amphibians. Can. J. Fish. Aquat. Sci. 37:1895-1905.

IJC. 1989. Proposed Listing/Delisting Criteria for Great Lakes Areas of Concern. Focus on International Joint Commission Activities. Volume 14, Issue 1, insert.

Matson, T.O. 1990. Estimation of Numbers for a Riverine Necturus Population Before and After TFM Lampricide Exposure. Kirtlandia 45:33-38.

National Research Council of Canada. 1985. TFM and Bayer 73 – Lampricides in the Aquatic Environment. NRC Associate Committee on Scientific Criteria for Environmental Quality. NRCC Publication No. 22488 pp.184.

New York State Department of Health. 2002. 2002-2003 Health Advisories for Chemicals in Sportfish and Game.

Ohio Sea Grant. 1999. Research review, Zebra Mussels: Key to Contaminant Cycling. Twine Line. Vol 21/No. 4.

Rouse, J.D., C.A. Bishop, and J. Struger. 1999. Nitrogen Pollution: An assessment of the impact on amphibians. Env. Health Persp. 107:1-6.

Straughan, Cameron A., Matthew Child, and Derek Coronado. 1999. Detroit River Update Report (Final Draft). Presented to the Detroit River Canadian Cleanup Committee.

United States Environmental Protection Agency. 1999. Mercury Meeting, Binational Meeting, Detroit, Michigan, USA. Cited in Straughan et al. 1999.

Section 5: Sources and Loads

Photo: U.S. EPA Great Lakes National Program Office

5.1 Approach and Direction

The Sources and Loads Subcommittee is charged with the task of identifying sources and loads of pollutants identified by the Lake Erie LaMP process. The Subcommittee continues to describe the status and trends in concentrations of pollutants, identify major pollutant sources in the basin, and provide an information base upon which to support sound management decisions for reducing, removing and eliminating these pollutants from the Lake Erie system. The Subcommittee also works to identify information gaps, and recommend the information required to fill those gaps.

An initial list of chemicals selected for intensive review was identified by the beneficial use impairment assessment reports (Table 5.1). Two substances, PCBs and mercury, were designated as Lake Erie critical pollutants due to documentation that they created impairment across the basin, particularly in relation to fish and wildlife consumption advisories. As the Lake Erie LaMP progresses and specific problems and causes become better defined, additional chemicals may be designated as critical pollutants.

Table 5.1: Pollutants Causing Beneficial Use Impairments in the Lake Erie Basin

Beneficial Use Impairment	Causes of Impairment
Fish & Wildlife Consumption Restrictions	*Fish* – PCBs, mercury, lead, chlordane, and dioxins *Wildlife* – PCBs, chordane, DDE, DDT and mirex
Fish Tumors or Other Deformities	PAHs
Bird or Animal Deformities or Reproduction Problems	PCBs, other organochlorines, dieldrin, DDE, PAHs, nitrates
Degradation of Benthos	Sediments contaminated with PCBs, other organochlorines, pesticides, PAHs
Restriction on Dredging Activities	PCBs and heavy metals
Eutrophication or Undesirable Algae	Phosphorus
Recreational Water Quality Impairment	PCBs[1], PAHs[1], Exceedances of *Escherichia coli* or fecal coliform guidelines

[1]PAHs are the basis for a human contact advisory in the Black River Area of Concern (Ohio), and PCBs are the basis for a human contact advisory in the lower Ottawa River, part of the Maumee Area of Concern (Ohio). The human contact advisories were issued by the Ohio Department of Health and recommend that contact with the sediment or water in these areas be avoided.

Table 5.2: Contaminants Identified as Lake Erie LaMP Pollutants of Concern

Contaminant(s)	Common Source(s)
Organochlorine insecticides and biocides	
DDT[2,3,4,5,6,8] • *DDD, DDE*	Historical use on crops, microcontaminant in dicofol
Chlordane[2,4,5,8] • *Alpha-chlordane, Gamma-chlordane, cis-nonachlor, trans-nonachlor*	Historical use on crops and for termite and ant control
Dieldrin[2,4,5,6,8]	Historical use on crops, termite and moth control
Toxaphene[3,4,5,6,8]	Historical use on crops, topical insecticide
Mirex[3,4,5,6] • *Photomirex*	Historical use for fire ant control and flame retardant
Alpha-hexachlorocyclohexane Beta-hexachlorocyclohexane Delta-hexachlorocyclohexane Gamma-hexachlorocyclohexane	Agricultural and topical insecticides
Industrial Organochlorine compounds or byproducts	
PCBs[2,3,4,5,6,8]	Transformers, hydraulic fluids, capacitors, heat transfer fluids, inks, casting waxes
Dioxin (2,3,7,8-TCDD)[4,5,6]	Combustion byproducts, contaminant in pentachlorophenol wood preservative, other chlorophenols and derivatives, including herbicides
1,4-Dichlorobenzene[4,5]	Mothballs, household deodorants, other biocides
Pentachlorobenzene[4,5] 1,2,3,4-Tetrachlorobenzene[4,5] 1,2,3,5-Tetrachlorobenzene[4,5]	Chemical synthesis
Pentachlorophenol[4,5]	Chlor-alkali plants, wood preservatives
Hexachlorobenzene[4,5,8]	Byproduct of chemical manufacturing, historical wood preservative and fungicide
3,3′-Dichlorobenzidine[4,5]	Plastic manufacturing, glues and adhesives, dyes and pigments for printing inks
4,4′-Methylenebis(2-chloroaniline)[4,5]	Plastics, adhesives
Polynuclear aromatic hydrocarbons (PAHs)[4,5,8]	
Anthracene, Benz(a)anthracene *Benzo(a)pyrene, Benzo(b)fluoranthene* *Benzo(k)fluoranthene,* *Benzo(g,h,i)perylene* *Chrysene, Fluoranthene, Phenanthrene* *Indeno(123-cd)pyrene*	Coal, oil, gas, and coking byproducts, waste incineration, wood and tobacco smoke, and forest fires, engine exhaust, asphalt tars and tar products
Trace Metals	
Alkyl lead[4,5,6]	Leaded gasoline
Cadmium[4,5]	Batteries, pigments, metal coatings, plastics, mining, coal burning metal alloys, rubber, dye, steel production
Copper[6]	Same as cadmium, plus plumbing and wiring
Lead[6]	Same as cadmium, plus solder
Zinc[6]	Same as cadmium, plus roofing
Mercury[3,4,5,6]	Batteries, coal burning, chlor-alkali plants, paints, switches, light bulbs, dental material, medical equipment, ore refining
Tributyl Tin	Antifouling paint, mildewcide, plastic stabilizer
Current-use herbicides[7]	
Atrazine, Cyanazine, Alachlor, Metolachlor	Agricultural herbicides
Other Contaminants	
Total phosphorus, Nitrate-nitrogen	Fertilizers and sewage
Fecal Coliform, *Escherichia coli*	Sewage and animal waste
Total suspended sediments	Soil erosion

[1]Contaminants indented are degradation products; those shown in italics have been identified as chemicals of concern
[2] Lake Erie Chemicals of Concern identified by Lake Erie LaMP in 1994
[3]Great Lakes Initiative Bioaccumulative Chemical of Concern (BCC)
[4]COA-Tier1 or Tier 2 contaminant
[5]Binational Toxic Strategy contaminant
[6]Contaminant identified by the IJC or in Remedial Action Plans
[7]U.S. EPA
[8]Canadian Toxic Substance Management Policy – Track 1

The Sources and Loads Subcommittee also compiled a second, more comprehensive list of pollutants and their degradation products designated by a variety of agency programs as being pollutants of concern within the Lake Erie basin (Table 5.2). This expanded list formed the basis for evaluation of information on all the pollutants of concern in Lake Erie to determine the suitability of the data for estimating loads and whether there are ongoing sources or pathways of contamination to the Lake Erie ecosystem.

In 2000, the Subcommittee provided an overview of the results of the *Characterization of Data and Data Collection Programs for Assessing Pollutants of Concern in Lake Erie* (Painter et al., 2000) to the LaMP. Briefly, this study characterized the information available from both the U.S. and Canadian public sectors and research laboratories in digital databases, and assessed the suitability of these data for identifying sources and characterizing pollutant concentrations and loadings to Lake Erie.

In general, data for nutrients (phosphorus and nitrate-nitrogen), suspended sediment and atrazine (an in-use pesticide) were considered likely to be adequate for characterizing tributary and point source concentrations and loads to the lake. However, for the organochlorine compounds, PAHs and trace metals, the majority of the databases were considered to contain data of insufficient quality and quantity or to be not applicable to characterize tributary, lake, or point source concentrations or annual loads to Lake Erie within acceptable levels of uncertainty. The insufficiencies were due to a number of factors, including the past use of methods that do not meet current quality assurance and quality control specifications for sampling in the part per billion and part per trillion concentration ranges, at which many of these compounds are now known to persist in the environment.

Concentration data for aquatic bed sediments and fish tissue were determined to be less susceptible to the limitations of quality and quantity than the organochlorine, PAH and trace metal data reported for surface water. Although not suitable for computing loads, these data could provide a strong indication of the extent and severity of contamination in the Lake Erie basin, and could be used to help indicate important source areas.

The findings and recommendations made in the report have helped to guide the activities of the Subcommittee since that time. Because a binational commitment to virtually eliminate sources of persistent toxic substances has already been made, and given the relative inadequacy of existing data to compute loads for these pollutants, it was determined to be more productive to pursue methods other than the calculation of loadings to identify the major sources and pathways of critical pollutants in Lake Erie.

5.2 Integration of Basin-Wide Sediment Quality Data, 1990 – 2001 (U.S. and Canada)

The Sources and Loads Subcommittee is integrating available information from many jurisdictions in both the United States and Canada about the pollutants of concern and the Lake Erie critical pollutants. Ambient environmental information including sediment quality data, tissue residue levels in aquatic biota and other information sources, are being compiled into the Lake Erie Information Management System (LIMS) together with information about potential contaminant sources such as municipal and industrial discharge data. The integration of information is facilitating management discussions on possible sources of these pollutants in the Lake Erie basin.

As a priority activity, the Sources and Loads Subcommittee has integrated sediment quality data on a binational basis. Sediments are an appropriate medium for contaminant analysis, since many of the contaminants of concern preferentially adsorb to sediment. In addition, a great deal of sediment quality data already exists across the basin. As primary depositional material, sediments not only implicate potential sources of contamination, but they also are the substrate by which food web uptake begins. In the near future, the LaMP Sources and Loads Subcommittee will perform comparisons between contaminants found in sediments and those found in fish tissue.

Integration of the available information identified data gaps, and several studies were initiated to ensure a more comprehensive information base. For example, when recent information on the spatial distribution of open lake sediment pollutant concentrations was required for the project described above, Environment Canada and Ohio EPA collaborated on a study that provided open lake pollutant concentrations in surficial sediments for many historical and emerging chemicals of concern. The 1997/98 survey conducted by Environment Canada and Ohio EPA not only provided valuable information on the open lake spatial distribution of contaminants, but because an earlier 1971 Environment Canada survey had been conducted, a retrospective analysis of the trends over time was also possible (Painter et al. 2001). Encouragingly, PCB concentrations have declined lakewide. Concentrations are one third of what they were 30 years ago. Mercury concentrations have also similarly declined.

The sediment distribution of the two LaMP critical pollutants, PCBs and mercury, as shown in Figures 5.1 and 5.2, were originally presented in the 2002 LaMP report. These figures represent an evaluation of PCBs and mercury in bed-sediments as compared to predetermined aquatic biological effect levels called threshold effect levels (TEL) and probable effect levels (PEL) after Smith, et al. (1996).

Dioxin concentrations in surficial sediments of Lake Erie were unavailable prior to the study conducted by Environment Canada and Ohio EPA. The Canadian probable effect level (21.5 pg/g TEQ) (CCME, 1999) was exceeded at 40% of the sites, all in the western and south-central basins of the lake (Figure 5.3).

In addition, information was collected on the following pollutants: chlordane, a former-use pesticide typically used for controlling insects in the home; polynuclear aromatic hydrocarbons (PAHs), a complex series of compounds resulting from the incomplete combustion of fossil fuels such as coal, gasoline, fuel oils, and tar, but also from the combustion of wood; and lead, having historical uses in gasoline and now found in oil and coal combustion, metal refining and fabrication, and waste incineration. Concentrations of these pollutants are presented in Figures 5.4 to 5.6 as compared to biological effect levels described by Ingersoll et al. (2000) and MacDonald et al. (2000), represented as Threshold Effect Concentrations (TEC) and Probable Effect Concentrations (PEC).

Chlordane is found above the PEC (17.6 µg/kg) in and downstream of all major urban areas in the drainage area. This apparently has a slight impact on the western basin and south shore of Lake Erie, where exceedences of the TEC (3.24 µg/kg) are observed regularly. Less frequent are the occurrences of elevated chlordane above the PEC and TEC in bed-sediments along the north shore of Lake Erie (Figure 5.4).

Similar to chlordane, total PAHs (the sum of individual PAH compounds) are also found above the PEC (22,800 µg/kg) in and around all major urban centers within the drainage area. However, total PAHs are also found at concentrations exceeding the PEC in smaller urban areas, owing to the widespread abundance and persistence of PAH compounds in the environment. As expected, some of the highest concentrations (greater than 10 and 100 times the PEC) are found in heavily industrialized centers, but a few highly contaminated areas are isolated from major urban centers (Figure 5.5). These point-source signatures are manifest in the open lake environment, where concentrations exceeding the TEC (1,610 µg/kg) are found frequently in the western basin, the central basin and along the entire south shore. Fewer exceedences of the TEC are observed along the north shore of Lake Erie.

Similarly to chlordane and total PAHs, lead is found above the PEC (128 mg/kg) primarily in urban and industrial areas, and its distribution in the open lake basins is greater in the west compared to the east (Figure 5.6). Concentrations along both the south and north shores exceed the TEC (35.8 mg/kg), but exceedences are found more frequently along the south shore.

Figure 5.1: Total PCBs in bed sediments

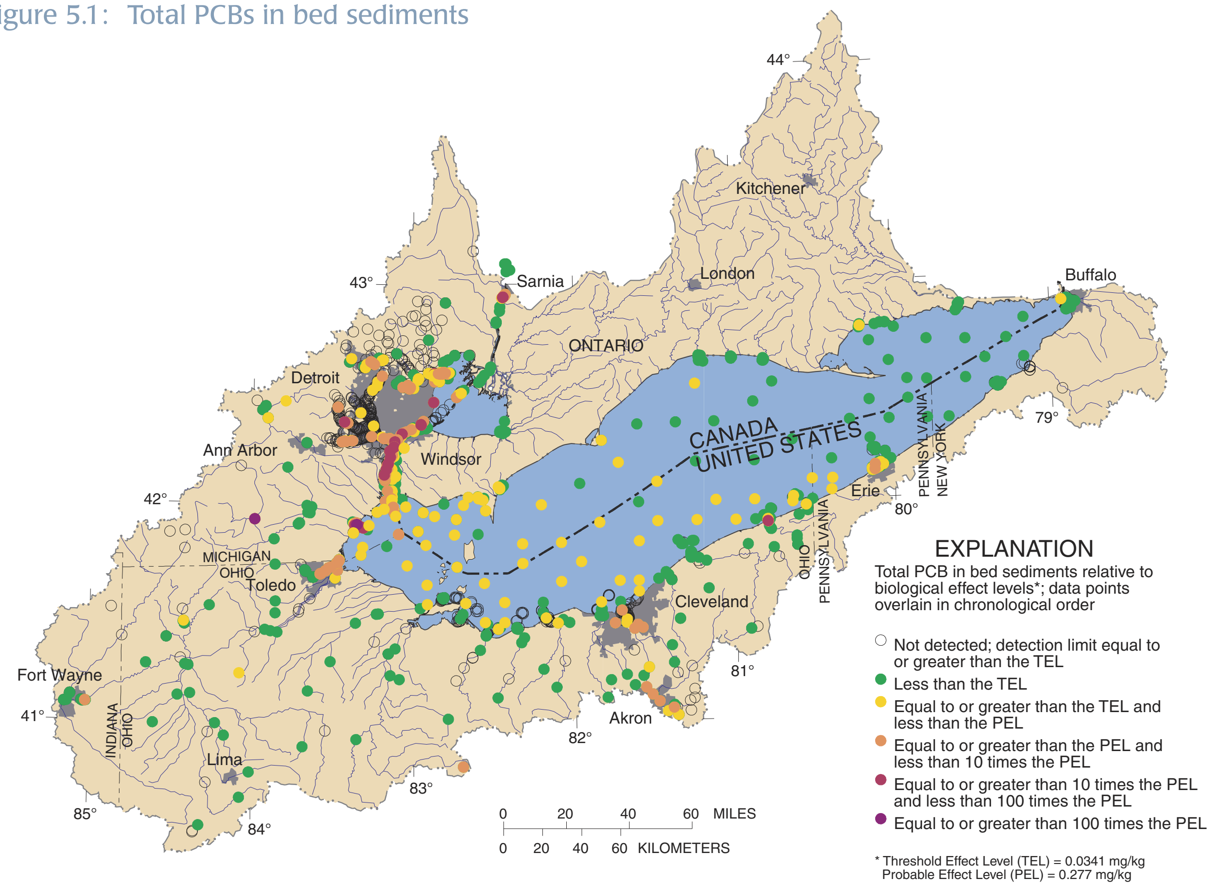


Figure 5.2: Total mercury in bed sediments

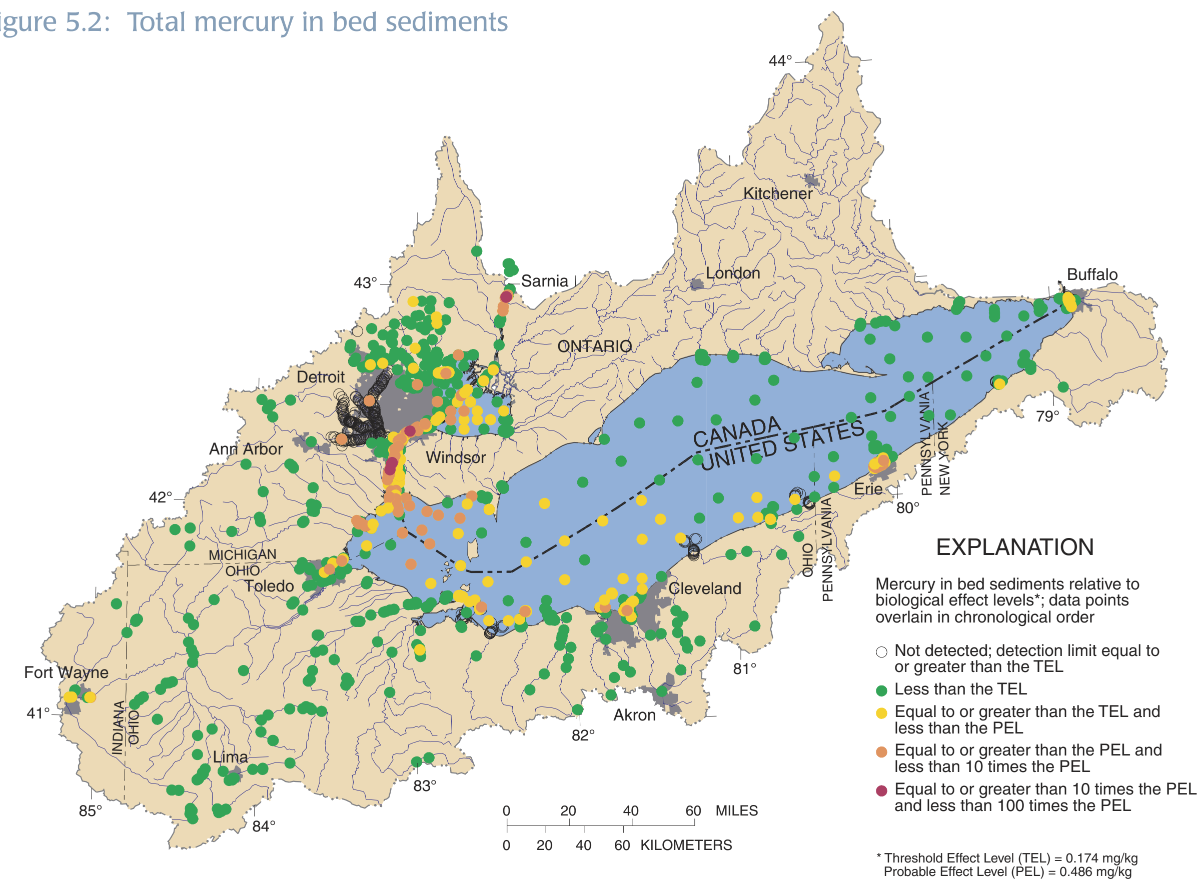


Figure 5.3: Surficial sediment concentration of dioxin (pg/g TEQ)

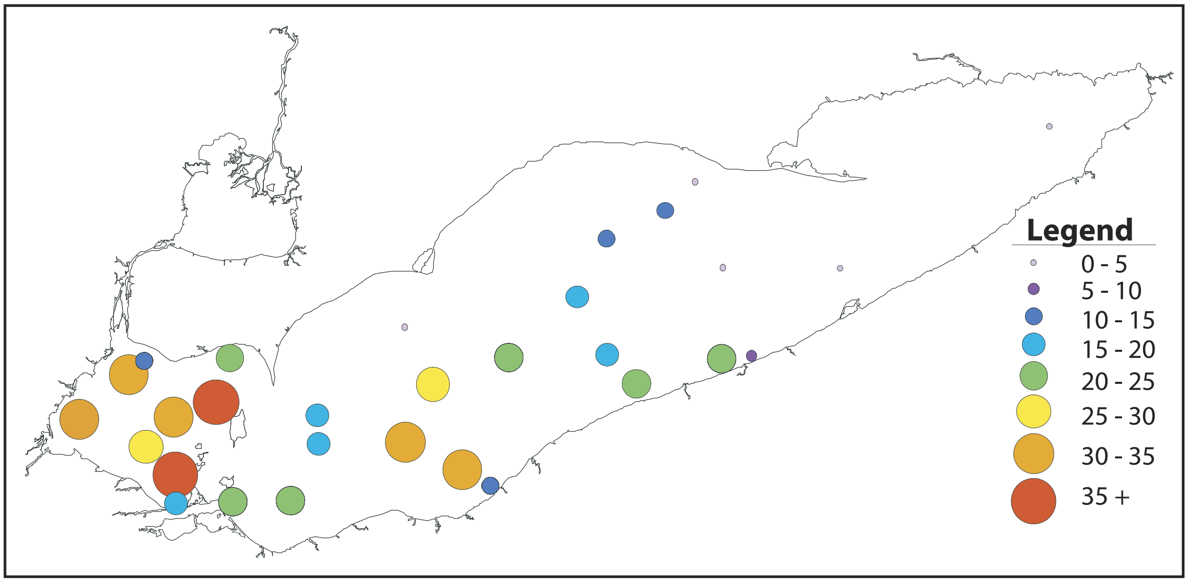


Figure 5.4: Total chlordane in bed sediments of the Lake Erie - Lake St. Clair basin, 1990-2002

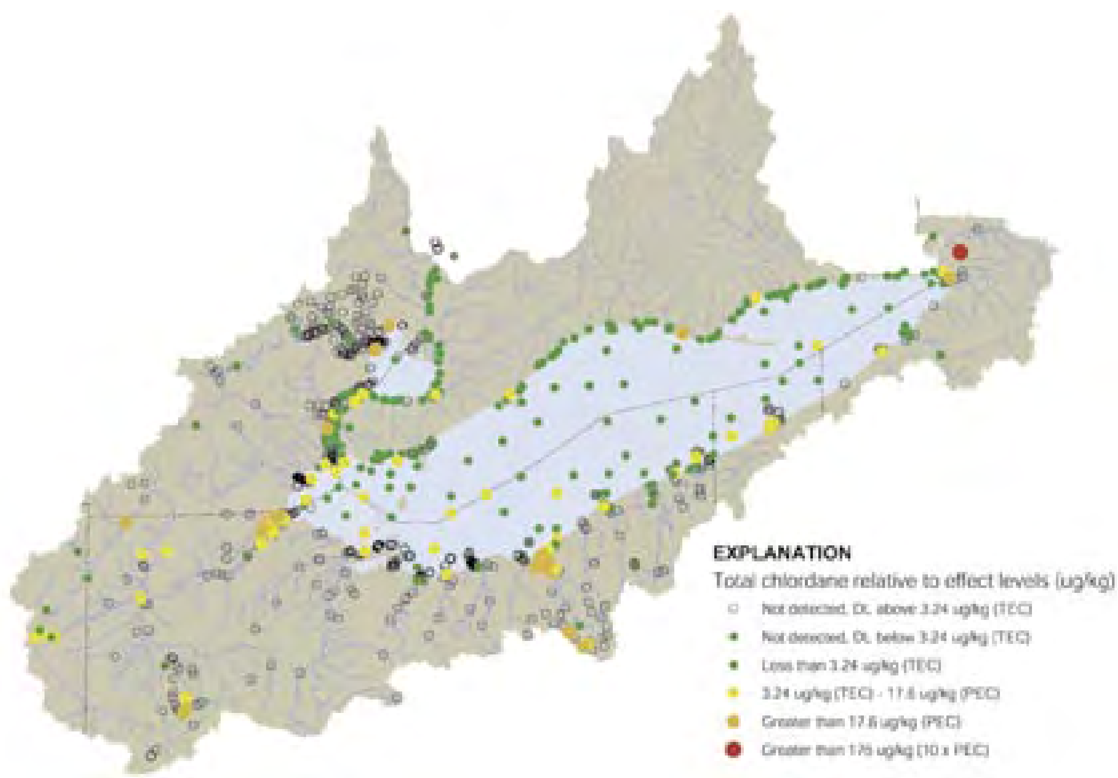


Figure 5.5: Total PAHs in bed sediments of the Lake Erie - Lake St. Clair basin, 1990-2002

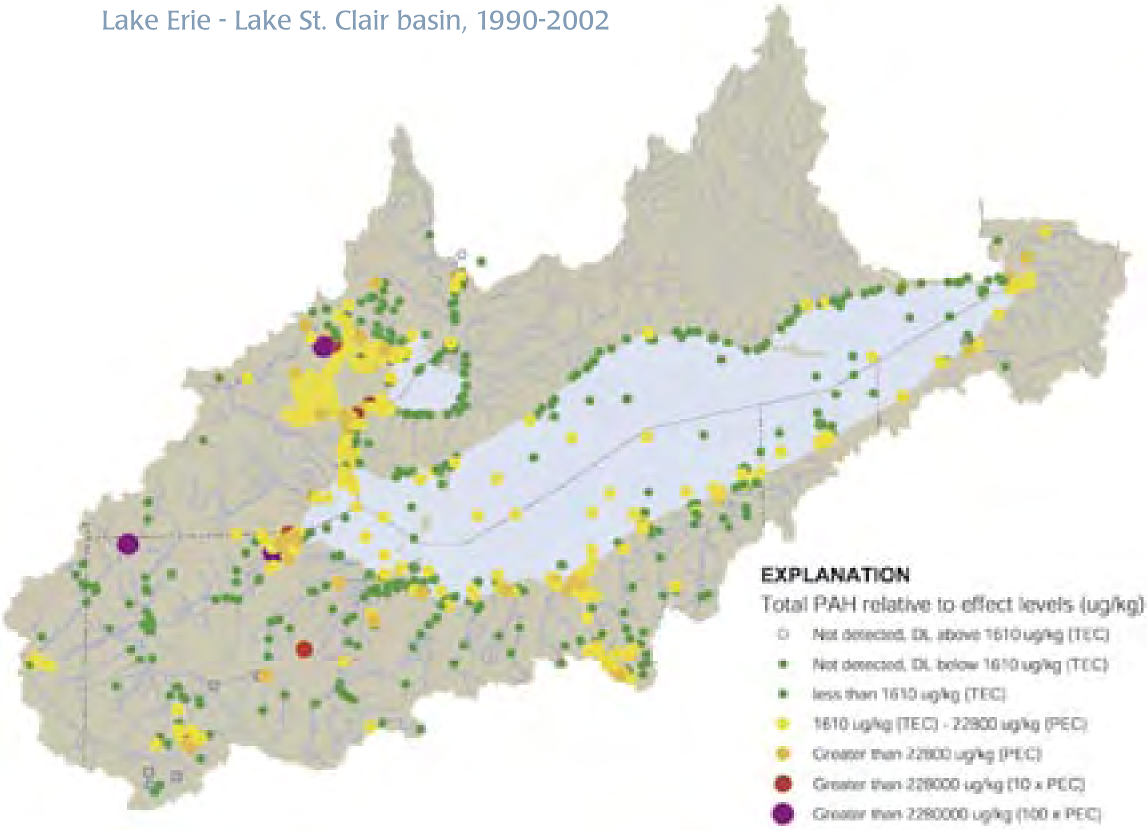
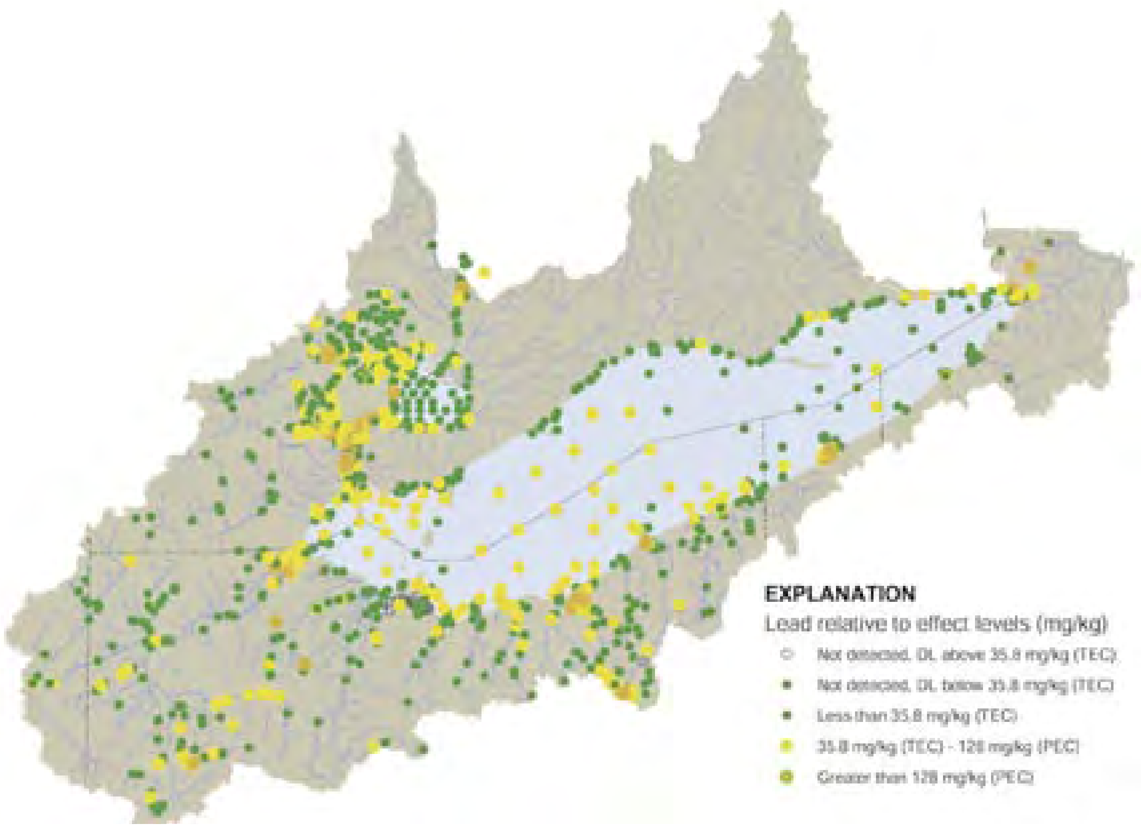


Figure 5.6: Lead in bed sediments of the Lake Erie - Lake St. Clair basin, 1990-2002



SMART (Sediment Management, Assessment and Remediation Team)

In an effort to organize the basin-wide assessment for the management and reduction of contaminated sediments, the Lake Erie LaMP Sources and Loads Subcommittee sponsored a meeting that convened in Presque Isle Bay State Park, Pennsylvania, in the summer of 2002. Representatives were from both Canada and the United States with national, state, and local interests. They included Environment Canada, Ontario Ministry of Environment, U.S. Environmental Protection Agency, U.S. Geological Survey, Michigan Department of Environmental Quality, Ohio Environmental Protection Agency, and Pennsylvania Department of Environmental Protection.

The opportunities for using a basin-wide sediment database from multiple sources mapped in a geographic information system (GIS) seem endless, however much of the discussion revolved around addressing a number of topics: 1) the completeness of the database, 2) the spatial distribution of different contaminants, 3) identifying key areas of the basin with apparent multiple contaminant issues, 4) determining if there are needs for new or additional monitoring, and 5) determining if there any known contaminated areas that are not being addressed at this time.

Key points made during the workshop with regards to management of contaminated sediments were that:

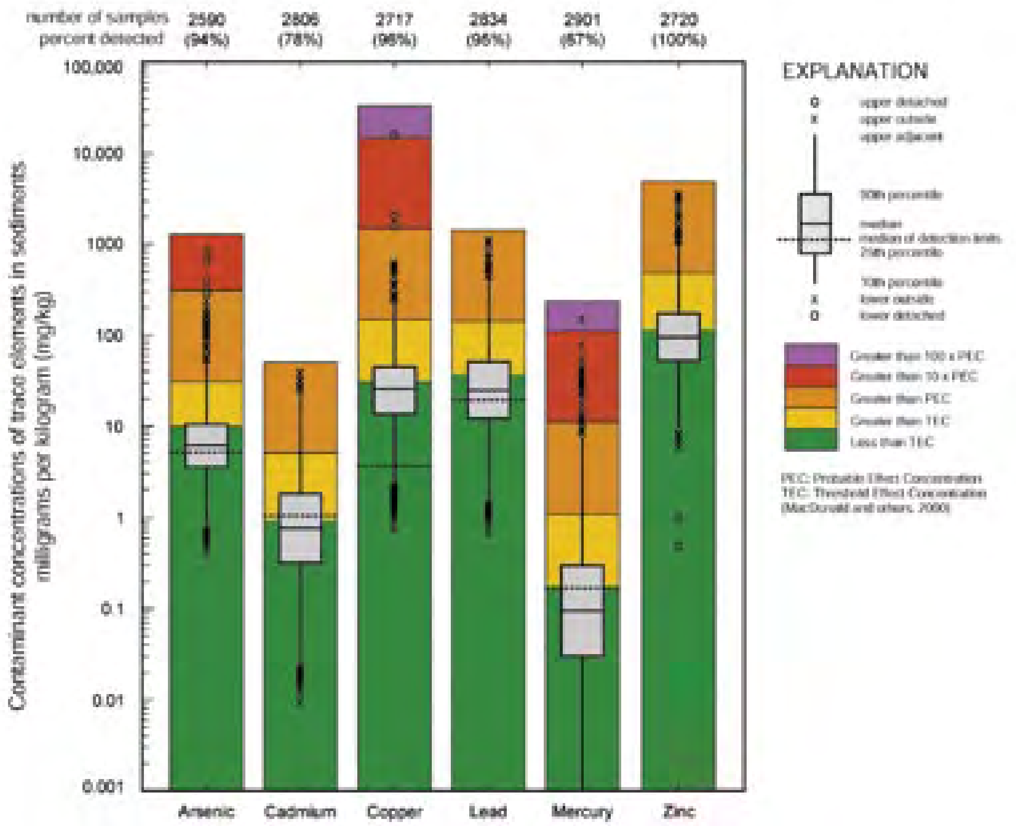
- Certain agencies have the programs and funding to clean up contaminated sediments, but lack an approved location to dispose of the sediments.
- The contamination quality typically left behind after dredging projects may still represent some of the most contaminated sites remaining in the basin. Sediment remediation efforts typically focus on highly contaminated hot-spots in well-defined zones, whereas sediment contamination in excess of biological sediment quality guidelines may be wide-spread. Moreover, criteria for sediment remediation (i.e., cleanup levels) are not as stringent as some sediment quality guidelines. To clean up to more stringent guidelines would be cost prohibitive, in many cases. However, the divergence between sediment cleanup guidelines and desired sediment quality must be addressed if we are to attain sediment quality that sets guidelines at contaminated sites in the Lake Erie basin.
- The apparent decreasing west to east gradient for many parameters in the open lake indicates that sources are primarily point sources into the system and not principally the result of atmospheric deposition.
- Controlling contaminant movement is not simple. Historically deposited contaminated sediments may be re-suspended and move downstream during storm events or may be disturbed by shipping activities.
- As point sources are identified and controlled, the role of non-point sources may become more important. Non-point sources such as contaminated soils and leaky landfills will be difficult to track, and their identification and control may represent a major challenge to further improvements in the open lake contaminant status.

5.2.1 Statistical Summaries of Contaminants in Bed Sediments

Concentrations of selected contaminants in bed sediments are summarized in Figures 5.7 to 5.9. The samples were collected during 1990 to 2003. These box plots represent both a statistical summary of the range of detected concentrations, as well as extrapolations of the non-detected samples (using the Adjusted Maximum Likelihood Estimator (AMLE) method for the interpretation of multiple samples with no detections, Helsel and Hirsch, 1993). The selected contaminants are depicted on a logarithmic scale relative to established biological effect levels: Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC), as developed by MacDonald et al. (2000). TEC and PEC values do not exist for mirex and hexachlorobenzene (HCB). Lowest Effect Levels (LEL) and Severe Effect Levels (SEL) (Persaud et al. 1993) were used instead.

Figure 5.7 shows a statistical summary of selected trace elements from the Lake Erie LaMP Pollutants of Concern Table 5.2, as well as arsenic. In each and every case, the median concentrations (50% of the results) are found to be below the TEC. This supports the understanding that high levels of trace element contamination are not systemic throughout

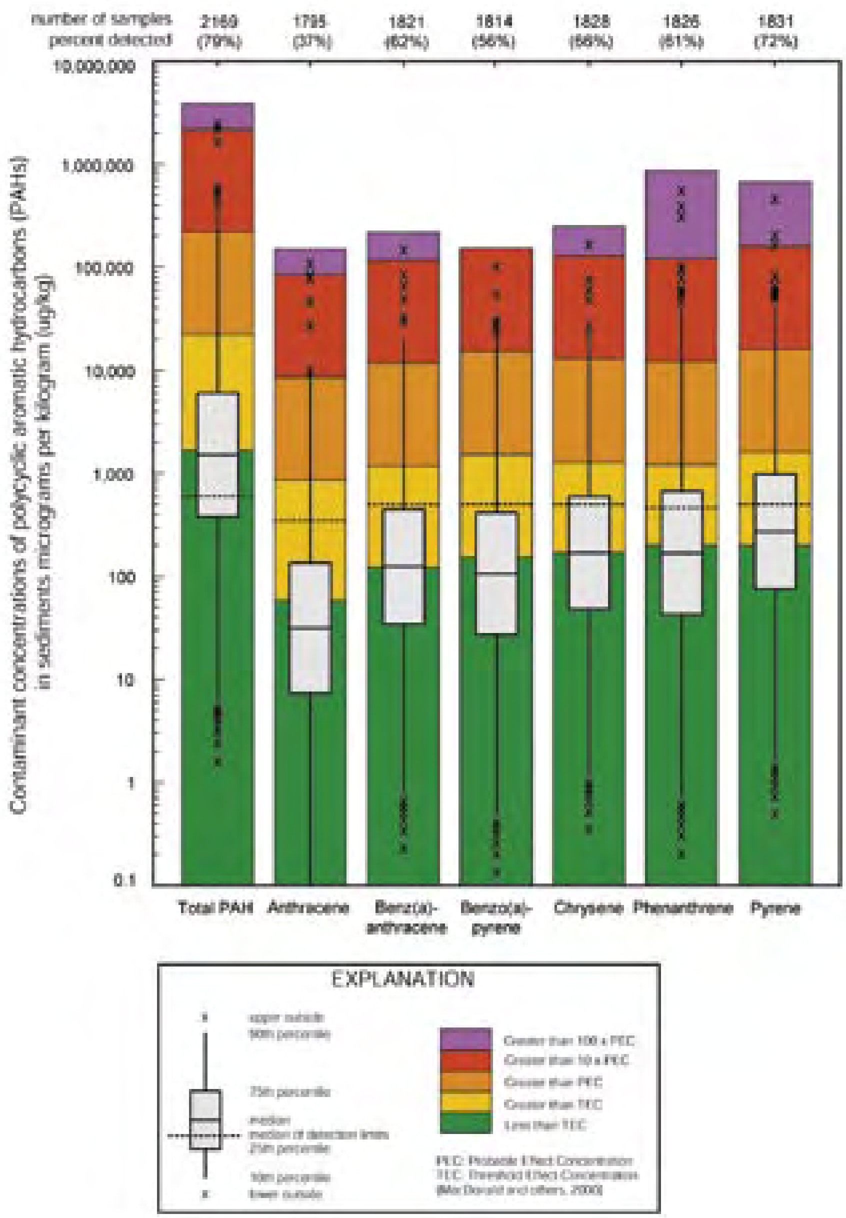
Figure 5.7: Summary statistics shown in boxplot format for trace element contaminants in bed sediments of the Lake Erie Basin, relative to biological effect levels. Data compiled from various provincial, state, local and federal agencies, 1990-2003.



the basin in either the tributaries or the open lake, but rather co-located with source areas such as urban-industrialized areas. Furthermore, for each contaminant, the top 25 percent of the sample results extend above the TEC, and the top 10 percent of each contaminant extends above the PEC. Percent detections range from 67 percent for mercury to 100 percent for zinc. Arsenic, copper and mercury all showed concentrations exceeding 10 times the PEC at discrete locations within the basin, while only copper and mercury were found to be exceeding the PEC by 100 times each at one location. The highest concentrations of trace elements, those exceeding the PEC, were found to be associated with, or downstream of, urban-industrialized areas such as: Buffalo, NY; Erie, PA; Cleveland, Akron, Lorain, Toledo, and Lima, OH; Monroe, Detroit, and Pontiac, MI; and Windsor and Sarnia, ON. For those samples with no detections, the median of detection limits were, for all contaminants except cadmium, at or below the TEC.

Total PAH represents either a lab measure result or a database calculated result of U.S.EPA's 16 most commonly measured PAHs. A statistical summary of total PAH and selected individual PAH compounds is shown in a series of boxplots represented in Figure 5.8. Frequency of detection ranged from 37 percent for anthracene to 79 percent for total PAH. More than half of the samples for anthracene, benzo(a)pyrene, chrysene, phenanthrene, and total PAH were found to be below the TEC, but for benz(a)anthracene and pyrene, more than half the samples were found to be above the TEC. Each contaminant and total PAH had greater than 25 percent of the results above the TEC, and the top ten percent of the samples were found to be above levels ten times greater than the PEC. All contaminants had at least one sample concentration exceeding 100 times the PEC, except for benzo(a)pyrene. Overall, individual PAH contaminants showed relatively the same statistical distribution pattern, while concentrations of total PAH were found to be at least one order of magnitude above individual contaminants. Both findings support the fact that multiple contaminants of PAHs are usually found together when a given source is present. Much like trace elements, the

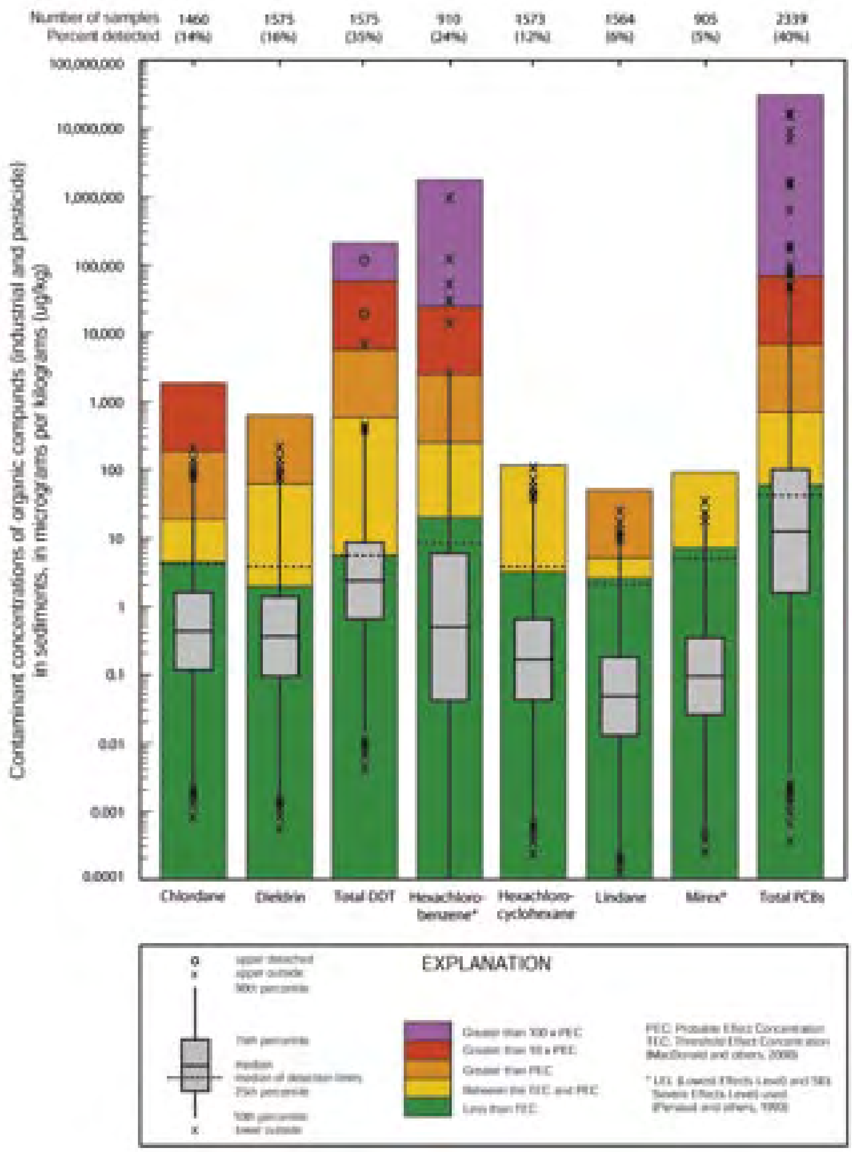
Figure 5.8: Summary statistics shown in boxplot format for PAH contaminants in bed sediments of the Lake Erie Basin, relative to biological effect levels. Data compiled from various provincial, state, local and federal agencies, 1990-2003.



high concentrations of PAH compounds were found to be near or downstream of urban-industrialized areas such as: Akron, Cleveland, Lorain, and Toledo, OH; Detroit and Pontiac, MI; and Sarnia, ON. However, high amounts of PAH contaminants in streams and inland lake sediments were also seen in rural communities in northwest Ohio where concentrations have been linked to creosote production and petroleum processing and refining.

Despite being banned from production almost 30 years ago, various manmade organochlorine contaminants are still persistent in the environment. They are still detected in bed sediments, and continue to bioaccumulate up through the food web. Figure 5.9 shows the statistical distribution of various organochlorine pesticides (DDT, dieldrin, mirex, lindane, chlordane, hexachlorocyclohexane, hexachlorobenzene) along with total PCBs, that were sampled from 1990 to 2003. The range of detected concentrations for the organochlorines is quite large, extending over 12 orders of magnitude from the lowest detection limit to the highest measured concentrations of total PCBs. Frequency of detection for organochlorine compounds was generally much lower than detections of trace elements or PAHs. Detection

Figure 5.9: Summary statistics shown in boxplot format for industrial and pesticide contaminants in bed sediments of the Lake Erie Basin, relative to biological effect levels. Data compiled from various provincial, state, local and federal agencies, 1990-2003.



frequencies for pesticides ranged from 35 percent for DDT to 5 percent for mirex. PCBs were detected 40 percent of the time.

Given the lower frequency of detection and the integration of the non-detections into the summary statistics, it is encouraging to see that the median concentration of organic compounds never exceeded the TEC or LEL. Moreover, only DDT and PCBs had greater than 25 percent of the samples above the TEC. Chlordane, dieldrin, and lindane (HCB-g) all had greater than 10 percent of their results above the PEC, while more than 10 percent of the samples from hexachlorobenzene (HCB-a,b,d,g) and total PCBs extended above 10 times the PEC. Individual samples of DDTs, hexachlorobenzene and total PCBs were found to be greater than 100 times the PEC.

The highest concentrations of organochlorine pesticides in stream and lake-bed sediments follow a pattern indicative of their historic use in residential, industrial and agricultural settings, and were found near or downstream of: Buffalo, NY; Erie, PA; Cleveland, Lorain, Lima, and Defiance, OH; Dundee, Monroe, and Detroit, MI; and Sarnia, ON. In all the organochlorine compounds, the median of the detection limits extended above the median measured concentration, and in the case of dieldrin and hexacholorcyclohexane, the median of the detection limits extended above the TEC or LEL. For all contaminants, when detection limits extend above the lower biological effects levels (TEC or LEL) they become too great to help with any interpretation of the sediments' effects on biological susceptibility.

A detailed summary of the bed sediment data analyzed for use in the LaMP 2006 Report, along with related fish tissue and source data, will be published by USGS in 2007.

5.3 Screening-Level Survey of Tributaries to the Lower Great Lakes (Canada)

Environment Canada, Ontario Region, has conducted a screening-level survey of sediment quality in tributaries to the lower Great Lakes. In 2001, approximately 100 Canadian tributaries to the St. Clair River, Lake St. Clair, the Detroit River and Lake Erie were sampled. Since that time, follow-up investigations have been conducted in selected Lake Erie watersheds. Virtually every tributary draining Ontario watersheds to the lower Great Lakes and their interconnecting channels are being sampled in this program.

To achieve the program objectives, a single, composite sediment sample is obtained from each tributary in a manner that maximizes the probability of detecting contaminants, if they exist, at the site. The targeted substances are relatively insoluble in water (i.e., hydrophobic) and, if present, are typically found at higher concentrations in sediments than in water. The sampling protocol is based upon the *Guidelines for Collecting and Processing Samples of Stream Bed Sediment for Analysis of Trace Elements and Organic Contaminants*, developed by the United States Geological Survey (USGS) for the U.S. National Water-Quality Assessment Program (NAWQA) (Shelton and Capel 1994). In the NAWQA program, downstream locations in watersheds are selected to provide a coarse-scale network of sites. At these integrator sites, large-scale problems that may not be detected in smaller basins have a reasonable chance of being detected.

The sediment samples are submitted for analysis of organochlorine compounds, PAHs, metals, total organic carbon and particle size distribution. Selected samples are also being screened for additional parameters such as dioxins and furans, polychlorinated napthalenes, polybrominated diphenyl ethers, in-use pesticides and other parameters of emerging concern, as resources permit.

The results of these surveys provide information about recently deposited sediment quality, and can be used to help identify if Canadian watersheds are sources of pollutants to the Great Lakes. The results are also used to prioritize sites for any subsequent follow-up work. An internal Environment Canada data report entitled *Sediment Quality in Canadian Lake Erie Tributaries – A Screening Level Survey* (Dove et al., 2002) has been shared with other environmental agencies, and confirmatory and/or follow-up work has already been initiated at all tributaries in the Lake Erie basin that showed elevated concentrations of either of the two Lake Erie critical pollutants, PCBs and mercury.

Photo: Environment Canada

5.4 Source Track-Down Project (Canada)

As part of a commitment to virtually eliminate the releases of persistent, bioaccumulative and toxic substances to the Great Lakes, the Ontario Ministry of the Environment (MOE) and Environment Canada (EC) have partnered to track down possible active sources of PCBs in Great Lakes watersheds. To date, three pilot projects have been undertaken in the Lake Ontario basin. Several objectives were intended for these pilot projects that are of interest to the Lake Erie LaMP:

1. To determine if such track-down projects are effective means of reducing local sources of PCBs;
2. To assess the effectiveness of various investigative tools;
3. To develop appropriate project design and methodologies, and;
4. To develop a guidance framework for future track-down projects.

The project partners have been working on developing the tools to help guide the selection, initiation and conduct of future track-down projects. It is anticipated that similar track-down projects will be initiated in Lake Erie. The initial focus will be to track down sources to tributaries that result in exceedences of environmental criteria near the point of discharge to Lake Erie. Projects would be initiated on a priority basis, with consideration of all available information to determine whether a track-down project would be warranted at a particular site.

5.5 Mercury and PCB Reduction Initiatives

The Great Lakes Binational Toxics Strategy (GLBTS) is the principle mechanism used by the LaMP to address pollution prevention and reduction initiatives for LaMP identified critical pollutants. Specifically, the GLBTS seeks to achieve reductions of use and/or release of various persistent bioaccumulative toxic substances, including mercury and PCBs, through voluntary agreements, projects and information sharing about cost-effective reduction opportunities for state, provincial and local governments, industry, and non-government organizations. This report provides a very brief overview of mercury and PCB activities. The GLBTS 2003 Progress Report (available online at www.binational.net) provides more detailed information.

National and International Activities

As with all the Great Lakes, Lake Erie receives deposition of airborne toxics from both distant and local sources. National and international programs have an important role in protecting Lake Erie from inputs of critical pollutants by reducing releases both within the basin and, in the case of pollutants that are atmospherically transported long distances, into the basin.

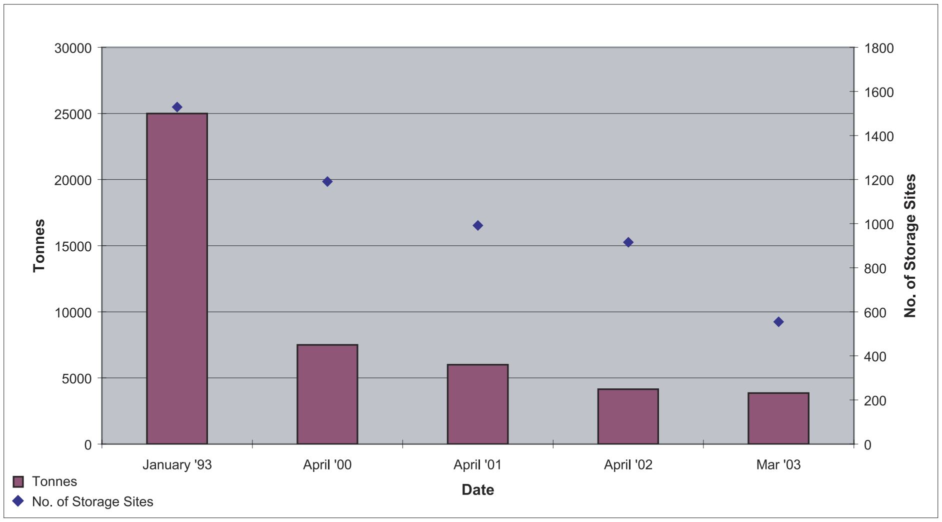
The United States and Canada have both signed the Stockholm convention on Persistent Organic Pollutants, which restricts the global production and use of twelve chemicals, including PCBs, dioxin, toxaphene, dieldrin, DDT, chlordane, and hexachlorobenzene (HCB). Canada has ratified this treaty and, in the United States the Senate Public Works and Environment Committee has recommended ratification. In addition, both nations are participating in the Mercury Programme of the United Nations Environment Programme, which has urged all countries to adopt goals and take actions, as appropriate, to identify populations at risk and to reduce human-generated releases of mercury.

At the national level, both countries have implemented actions to reduce air emissions of mercury, PCB, and other contaminants.

PCB Reduction Progress

The long-range transport of PCBs is a significant portion of the loadings experienced within the Lake Erie Basin. While the GLBTS 2003 Progress Report doesn't break out progress specific to the Lake Erie Basin, the report provides the broader context for loading reductions for Lake Erie.

Figure 5.10: High level PCBs and number of storage sites in Ontario



As of March 2003, approximately 85 percent of high-level PCB wastes in Canada had been destroyed, up from approximately 40 percent in spring 1998 when work in support of the GLBTS commenced. From April 2001 to March 2003, approximately 1,300 tonnes of high-level PCBs were destroyed (Figure 5.10), and as of April 2003, approximately 983 storage sites (both federal and private) were PCB-free (no PCBs in use or in storage), with about 555 sites still remaining.

Rates of PCB phase-out have declined in recent years because remaining PCB equipment is difficult or expensive to replace and the fate of the Canadian PCB incinerator in Swan Hills, Alberta, is uncertain. However, the Canadian government is planning to regulate PCB phase-out dates (see Table 5.3 for proposed PCB regulations). Awareness among owners continues to increase due to continuing PCB outreach, the PCB Phase-Out Awards Program (Canada), sector mail-out of information, and voluntary commitment letters. Newer facilities and options are now available in Ontario for PCB decontamination and destruction, in addition to the Alberta Swan Hills incinerator. Owners of large quantities of PCBs have been able to incorporate PCB phase-out and destruction activities into multi-year operating plans, but smaller businesses have difficulty absorbing a large capital expense in any one fiscal year.

The priority sectors in Ontario that still have a considerable amount of high-level PCBs in use include: iron/steel, governments, and mining/smelting. In addition, schools, care facilities, and food processing are priority sectors as sensitive areas that still have high-level PCBs in use. These sectors need to be targeted for PCB decommissioning. Sectors in Ontario that need to be targeted for destruction of high-level PCBs in storage include the provincial and municipal governments, iron & steel production, and the forestry/pulp and paper industry.

According to annual reports submitted to U.S. EPA, the estimated amount of PCB transformers and capacitors remaining in the U.S. at the beginning of 2001 is less than 129,000 PCB transformers and less than 1,332,000 PCB capacitors. The reports do not include PCB transformers that have been reclassified or some capacitors that may be on the reports under the category of PCB article containers. The 1999 PCB Transformer Registration Database shows that there are approximately 20,000 PCB transformers currently registered and in-use in the U.S., but the actual number remaining in use is likely higher. Nonetheless, reductions of PCB transformers and capacitors continue to occur. U.S. EPA continues to evaluate ways to try to better quantify the data and help track progress toward meeting the U.S. challenge.

Current Focus of PCB Reduction Efforts

The GLBTS PCB Workgroup plans to continue its core activities, including the following:

PCB Reduction Commitments:

The Workgroup will continue seeking commitments to reduce PCBs through PCB reduction commitment letters and other PCB phase-out efforts.

Outreach/Sharing Information:

The Workgroup will continue to develop, distribute, and post on the Workgroup website, information which can facilitate and promote, as applicable, the identification and removal of PCB equipment. These include: photographs of electrical equipment; fact sheets; case studies that identify reasons companies remove PCBs; and a standard presentation of the PCB Workgroup's challenges and activities. The Workgroup will also continue to consider incentives for removing PCB equipment.

ISO 14000 and PCBs:

The PCB Workgroup has decided to lobby the ISO (International Standards Organization) to include PCBs as a specific hazardous material to be managed and eliminated. If the ISO were to include PCBs as a targeted substance, it would encourage applicants for ISO status to plan for the elimination of their PCBs.

Property and Liability Insurance and PCBs:

After questions and discussion at the May 2003 GLBTS Stakeholder Forum, the PCB Workgroup decided to investigate ways that insurance companies handle PCBs as an insurance risk. If insurance companies see PCBs as an "additional risk" above and beyond other hazardous substances, then it would be an advantage to PCB owners to eliminate their PCBs and reduce their risk ratings. U.S. EPA is looking into the potential for insurance to be used as an incentive for companies to remove PCBs.

Photo: U.S. EPA Great Lakes National Program Office

Table 5.3: PCB Reduction Plan Activities Update 2004

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
Pollution Reduction		
Work with automotive, iron and steel sector and electrical facilities in the Lake Erie basin to establish voluntary commitments to reduce the use, discharge or emissions of PCBs.	**Canada:** (reductions noted below occurred in whole or in part in the Lake Erie Basin) ***Steel Sector:*** • Stelco achieved a 91 percent reduction of PCBs in storage and 41 percent reduction of in PCBs in service; • The steel sector continues to work toward a solution to the large amount of PCBs in use transformers and capacitors. ***Automotive:*** • The Canadian automotive industry destroyed 4,359 kgs and 133,495 litres of high-level PCBs across Ontario; • Daimler-Chrysler, Canada, removed all high-level PCBs from transformers and capacitors and sent them to the Swan Hills PCB-incineration facility for destruction. ***Utilities:*** • 42 electrical utilities submitted voluntary commitment letters to Environment Canada; • A number of small- to medium-sized utilities in Ontario achieved 90 percent or better high-level PCB reduction targets; • Hydro One has eliminated all high-level PCBs in its network; • Canadian Niagara Power has eliminated all high-level PCBs from its Niagara area network; • Festival Hydro (Stratford, Ont.) has eliminated all high-level PCBs; ***Others:*** • Canadian Petroleum Producers Association and its members eliminated 90 percent of PCBs; • City of Windsor and Essex County sent 65,000 kgs of PCB-contaminated materials to Swan Hills for destruction; • Public Works and Government Services Canada has implemented an aggressive PCB phase-out program and has eliminated over 90 percent of their PCBs across Ontario; • Conestoga College and Wilfrid Laurier University have eliminated all high-level PCBs from their inventories; • The Thames Valley District School Board, Coca-Cola (Chatham), and Frito Lay (Cambridge) are all PCB-free. **U.S.:** U.S. EPA began to finalize information for the nation wide outreach campaign on phasing out PCB equipment and investigated the use of a hotline number as the point of contact. In addition, in 2003, U.S. EPA funded an expansion of the outreach and PCB phase-out solicitation campaign that will enable additional facilities to be reached and provide for additional follow-up.	EC and U.S. EPA
Coordinate LaMP and GLBTS efforts with all related partners in order to produce a cohesive, unified program to address PCBs in the Great Lakes.	Ongoing	EC and U.S. EPA
U.S. EPA Superfund commits to completing the remedies for Springfield Township Dump (MI); G&H Landfill (MI); Metamora (MI); and Fields Brook (OH) by the end of 2002.	• Springfield Township Dump– Construction of remediation systems complete, including treatment and/or removal of 12,000 cy of sediment. Operation and maintenance is expected for the next 4 years. • G&H Landfill – Construction of onsite remedial technology (landfill cap and slurry wall) complete, wetlands restored, with groundwater extraction ongoing for at least 30 years. • Metamora – **COMPLETE** – Landfill cap constructed to contain 20,000 cy of sediment. • Fields Brook – The cleanup of Fields Brook sediment and floodplain soils is complete. 52,369 cy of sediment were removed. O&M at the on site landfill and monitoring of the brook and floodplain will continue. Remediation is also complete at the six separate source control operable units. NRDA restoration underway.	U.S. EPA

Committed Action (2000 LaMP)	**Status (2004)**	**Lead Agency**
Formalize the PCB Phasedown Program pilot project with the major utilities in the Great Lakes basin. Program is designed to encourage the utilities to phase out PCB equipment.	U.S. EPA Region 5 received comments from industry representatives on components of the PCB Phasedown Program that may improve participation in the program. The Region is evaluating changing the components to address the comments.	U.S. EPA
Identify federally owned PCBs in the Lake Erie basin and seek their removal by the departments or agencies that own the PCBs.	**Canada:** Federal PCB database complete. Database is read-only and is limited to those with an approved login account. **U.S:** As the study on the costs of the use and removal or replacement of PCB equipment continued, additional approaches to work with federal departments or agencies on removing PCB equipment they owned were pursued. U.S.EPA has begun to contact some of the owners to discuss PCB reduction challenges and requirements to register PCB transformers with U.S.EPA.	EC U.S. EPA
Organize small PCB owner workshops in the Lake Erie basin to exchange information on PCB management, decommissioning and destruction.	Information packages distributed in Sept. 2001 included PCB Owner Outreach Brochure, GLBTS-PCB Workgroup Activity Regional Update, and fact sheet on Ontario PCB In Use Inventory survey and a map showing PCB quantity and location in the Lake Erie basin.	EC and MOE
Encourage PCB owners to destroy PCBs in use or storage.	• PCB phase out commitment letters have been received from Ontario Power Generation to phase out and destroy approximately 81% of their high level PCB by 2001 and 100% by 2015. • PCB phase out commitment letter requests have been sent to the Council of Great Lakes Industry trade associations including: Aluminum Association of Canada and the Canadian Petroleum Products Institute. • A survey of over 2,000 PCB equipment owners was completed in 2002 in order to track de-commissioning progress and obtain commitments for phase-out. • A PCB Phase-Out Award program was initiated to give recognition to facilities that have conducted phase-outs. Environment Canada is also developing case studies for those that receive an award, in order to promote phase-outs and provide examples of beneficial factors considered when companies decide to remove PCBs. • Environment Canada has developed a GLBTS PCB Newsletter that will be used to promote the PCB elimination and award programs. The purpose of the newsletter is to summarize information about the GLBTS, PCBs as an environmental hazard, the Phase-Out Awards Program, and other issues in an eye-catching, simplified format.	EC
Information		
Finalize the PCB Sources and Regulations Background Report.	**COMPLETE.** The report is available at www.epa.gov/glnpo/bns/pcb/index.html	EC and U.S. EPA
Finalize the PCB Options Paper under the GLBTS that identifies options that can be undertaken to reduce PCBs in the environment.	**COMPLETE.** The report is available at www.epa.gov/glnpo/bns/pcb/index.html	EC and U.S. EPA

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
Report on an annual basis the status of sediment remediation at priority sites within the Lake Erie basin.	**COMPLETE** for priority sites within Areas of Concern see Great Lakes Binational Toxics Strategy Annual Report at www.binational.net	EC and U.S. EPA
Regulation		
	Canada: A notice with respect to PCBs in Automotive Shredder Residue was published in Gazette I on July 7, 2001 for facilities that generated residue contaminated with PCBs during 1998 – 2000. Four Environment Canada PCB regulations are being amended and targeted for Canada Gazette publication in 2004. These regulations are: 1) The Chlorobiphenyl Regulations (1977), 2) The Storage of PCB Material Regulations (1992), 3) PCB Waste Export Regulations (1996), and 4) Federal Mobile PCB Treatment and Destruction Regulations. Environment Canada is currently drafting revisions to the Chlorobiphenyl Regulations and Storage of PCB Materials Regulations under the Canadian Environmental Protection Act. The most significant revisions to the regulations will be the imposition of strict phase-out dates for certain categories of PCBs. Specifically, the following dates are proposed: • Phase-out of most high-level (>500 ppm) PCBs in-service by the end of 2007, • Phase-out of most low-level (50-500 ppm) PCBs in-service by 2014, • Phase-out of all PCBs in storage by the end of 2009 and allow in-service PCBs to be transferred to storage for one year or less, • Phase-out of most high-level and low-level PCBs from sensitive locations within three years of the proposed regulations coming into force, • Decontamination of all out-of-service liquids containing PCBs to less than 2 ppm (previously liquids and solids up to 50 ppm could be re-used, recycled, or disposed in a landfill). Revisions to the Federal Mobile PCB Treatment and Destruction regulations will see the strengthening of emissions release provisions, mainly to bring the federal regulations in line with existing provincial requirements. Extensive public consultation was conducted, and the revised regulations should be published in the Canada Gazette in early 2004. More information and updates can be found on the Environment Canada website (http://www.ec.gc.ca/pcb/). **U.S.:** In the Federal Register of July 30, 2003, a final rule was published with an effective date of September 9, 2003, that clarified how used oil that is contaminated with PCBs is regulated, as follows: • Used oil containing PCBs at concentrations of 50 ppm or greater is subject to Federal PCB regulations. Dilution may not be employed to avoid this regulation, unless otherwise specifically provided for by the RCRA or Federal PCB regulations. • Used oil containing PCBs at concentrations less that 50 ppm is subject to the RCRA used oil management standards, unless it has been diluted (from 50 ppm or greater), in which case it is treated as having 50 ppm or greater PCBs.	EC and U.S. EPA

Mercury Reduction Progress

In Canada, mercury releases have been reduced by 83 percent from the 1988 baseline. Releases in Ontario have been cut by more than 11,600 kilograms since 1988, based on Environment Canada's 2001 mercury inventory. The largest remaining sources of mercury release in Ontario are electric power generation, incineration, iron & steel production, municipal sector, and cement and lime production.

U.S. mercury emissions decreased approximately 40 percent between 1990 and 1999, according to best estimates from the National Emissions Inventory. It is likely that some additional reductions have occurred since 1999, particularly in emissions from municipal waste combustors and medical waste incinerators. Significant reductions in emissions from these sectors had already taken place by 1999, but compliance with emissions regulations for these categories was not required until after 1999. By 2006, additional regulations and voluntary activities are expected to reduce mercury emissions a total of 50 percent or more, achieving the reduction challenge.

While U.S. mercury use declined in the late 1990s, progress since 1997 is difficult to gauge quantitatively given changes in the sources of data about mercury consumption. Available data indicate that mercury use declined more than 50 percent between 1995 and 2001; much of this decrease is attributable to decreased mercury use by the chlor-alkali industry, which accounted for an estimated 35 percent of mercury use in 1995. For a more detailed evaluation of data and assessment of progress, see http://www.epa.gov/region5/air/mercury/progress.html.

Consumer and commercial products have been significant sources of mercury. Mercury-containing products can include thermometers, switches, dental amalgams, thermostats, button batteries, and fluorescent lamps. Industrial raw materials can also contain unwanted mercury. The elimination of mercury from latex paints and batteries was a significant pollution prevention success of the manufacturing sector in the 1990s. Also, the amount of mercury contained in fluorescent lamps has been reduced.

Numerous mercury reduction activities are occurring in both Canada and the U.S. to meet the GLBTS goals regarding mercury reductions (refer to the GLBTS 2003 Progress Report, available online at www.binational.net). For example, voluntary mercury reduction agreements are being implemented with the chlor-alkali industry and hospitals. For more details and information about other reductions projects and programs check out: http://www.epa.gov/Region5/air/mercury/mercury.html.

Regulation of municipal waste, hospital waste, hazardous waste, and sludge incinerators is yielding significant reductions in air emissions of mercury. Canada-wide Standards for these sources have begun to go into effect. Canada-wide Standards have also been developed for the coal-fired Electric Power Generation sector, for mercury-containing lamps, and for dental amalgam waste. These standards are outlined at http://www.ccme.ca/initiatives/standards.html) which also provides a broader overview of the Canada-wide Standards process and implementation. In the United States, control standards for small municipal waste combustors were finalized, and compliance is already required at large municipal waste combustors, hospital incinerators, and hazardous waste combustors. Also in the United States, mercury reduction requirements have been finalized in the last two years for mercury cell chlor-alkali plants and iron foundries, and proposed for industrial boilers. Emissions from electric utility boilers, the largest source of mercury emissions in the United States, will be controlled either as a result of a control technology regulation or legislation that controls emissions of mercury along with sulfur and nitrogen. Canada-wide standards are also being developed for this sector.

In June 2001, Pollution Probe, with support from Ontario Hydro, Ontario MOE and Environment Canada, initiated a switch out program to recover mercury switches from end-of-life vehicles. In partnership with the Ontario Automotive Recycling Association the program began with 11 participating auto dismantlers across Ontario. In 2004 the program has grown to include over 130 participating dismantlers in Ontario and has been expanded to other Canadian provinces.

Current Focus of Mercury Reduction Efforts

The GLBTS Mercury Workgroup will continue to focus on information sharing about cost-effective reduction opportunities, tracking of progress toward meeting reduction goals, and publicizing voluntary achievements in mercury reduction. Particular attention will be paid to information sharing in areas where mercury releases are significant but there are no federal regulations existing or regulations are under development. For instance, the workgroup will attempt to focus attention on the contamination of metal scrap by mercury-containing devices, and the resulting emissions, and provide a forum for discussion of cost-effective approaches to address this problem. In addition, the workgroup will focus on the issue of mercury releases from dental offices and will help state, provincial and local governments identify cost-effective reduction approaches for this sector. There will also be a focused discussion of options for minimizing mercury releases resulting from the disposal of mercury-containing lamps.

Table 5.4: Mercury Reduction Plan Activities Update 2004

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
Lake Erie Basin		
Continue to implement Elemental Mercury Collection and Reclamation Program in Ohio (www.bgsu.edu/offices/envhs/environmental_health/mercury/index.htm).	Since the program began in 1998, 7200 lbs of mercury have been removed.	Ohio EPA
Establish a household hazardous waste collection facility to collect and recycle household products containing mercury in the cities of London and Waterloo, Ontario.	**COMPLETE** Fluorescent lamp collection facilities are available to households in London, Chatham-Kent, Guelph, Brantford, and Wellington County. A Mercury Thermometer Take-Back project was conducted in 2002 in the cities of London (Erie basin), Ottawa, and Thunder Bay. A total of 1.5 kg of mercury was collected.	EC
Continue P3ERIE (Pollution Prevention Partnership & Environmental Responsibility in Erie).	An additional 4,000 pounds of elemental mercury has been collected from businesses, schools, and private citizens in the greater Erie area since 2000. Well over three tons of mercury have been collected and recycled since the inception of the program. Most recently, P3ERIE has initiated a pollution prevention initiative with the PA Dental Association. www.dep.state.pa.us/dep/deputate/pollprev/P3erie/p3erie.htm	
Great Lakes Basin		
U.S. EPA (Air and Radiation Division) has committed funds to support mercury research in a number of priority areas including transport, transformation and fate, and human health and wildlife effects of methyl mercury.	This program provides more than $1 million per year for research on mercury and other air deposited pollutants in the Great Lakes Basin, focusing on persistent toxic pollutants. Since 2000, projects have been funded to better understand mercury transport, transformation and fate in the environment. Starting in 2003, ARD has (and will in the future) awarded a grant to the Great Lakes Commission to oversee the competition and selection of air deposition research proposals.	U.S. EPA
U.S. EPA filed civil complaints against seven electric utility companies operating coal-fired power plants in the Midwest and Southeast.	U.S. EPA eventually filed a total of nine cases, and has settled two of them, received favorable judgment in one, is awaiting a judge's decision in one, is in discovery on four, and received an unfavorable judgment on another.	U.S. EPA
EPA will continue to focus on research efforts and potential regulation of mercury emissions from coal-fired utilities.	On January 30, 2004, EPA published proposed regulation of the emissions from coal-fired electric utility boilers, the largest source of mercury emissions in the United States. The proposal includes two primary regulatory alternatives. The first is a control technology standard that would achieve 29 percent reduction in mercury emissions by 2009. Under this option, EPA would impose emission rate limits on individual boilers in pounds per megawatt hour of electricity generated. The other option is a two-phase "cap-and-trade" program, ultimately resulting in emissions reductions of 69 percent. This program would be implemented through state plans, under which states would receive mercury emissions "budgets" that they could meet either by setting emissions limits on individual boilers or by distributing mercury emissions allowances. These allowances could be traded with other sources across the country or banked for future use. The first phase of reductions would begin in 2010, with the final phase in 2018.	U.S. EPA

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
Michigan Department of Agriculture: Michigan Mercury Manometer Disposal grant was used to replace mercury manometer gauges used on dairy farms with non-mercury gauges. Mercury was also collected from inactive dairy farms.	**COMPLETED.** Project Period: 10/1/99 top 9/30/00.	U.S. EPA
Indiana University: Deposition of toxic organic compounds to the Great Lakes. The Integrated Atmospheric Deposition Network Grant provides funds for the operation and maintenance of the Integrated Atmospheric Deposition Network (IADN) by Indiana University.	A new cooperative agreement was awarded to IU for continuation of network through September 2004. Satellite station added at Cleveland in early 2003. New implementation plan for IADN will be signed in 2004.	U.S. EPA
The Integrated Atmospheric Deposition Network Quality Assurance and Quality Control Program Grant. The Great Lakes National Program Office (GLNPO) is collaborating with Environment Canada (EC) to implement the Binational Integrated Atmospheric Deposition Network as mandated by Annex 15 of the Great Lakes Water Quality Agreement and Section 112(m) of the Clean Air Act.	Ongoing.	U.S. EPA and EC
By the end of 2000, the U.S. EPA will work with states to develop a permitting strategy consistent with the Clean Water Act for reducing loading of mercury from industrial, municipal, and storm water sources to further the goals of the LaMP.	**COMPLETED.** Lake Erie states have developed NPDES mercury permitting strategies that incorporate method 1631 and the new GLI limits and multiple discharger variance rules.	U.S. EPA
U.S. EPA identifies point source dischargers of mercury which are monitored by NPDES permittees using the permit compliance system and shares this information with wastewater treatment plants, industry, tribes and other contributors of mercury to the extent they are relevant sources. U.S. EPA will also inform states and regulated communities about sources of unregulated pollutants of concern and share available information regarding potential substitutes and waste minimization strategies.	U.S.EPA has been using the permit compliance system in working with states on implementation of their permitting strategies and tracking mercury reduction results at permittees.	U.S. EPA
U.S. EPA Region 5 will support the rigorous development and refinement of the Regional Air Toxics Emissions Inventory of all hazardous air pollutants, including those of concern to the Great Lakes and other inland water bodies and which have a tendency to bioaccumulate. U.S. EPA will work closely with all eight Great Lakes states to assure every possible known source of all magnitudes of emissions is identified and that good emissions estimates are developed and updated to reflect the implementation of control technologies and progress in emission reductions for input to air dispersion and deposition models.	U.S. EPA has continued to support development and improvement of emissions inventories through funding for the Regional Air Pollutant Inventory Development System. The RAPIDS project had a specific task to improve the regional emissions inventory for mercury.	U.S. EPA

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
U.S. EPA commits to ensuring that all Region 5 states will have enforceable regulations and the permit applications that are required to be submitted for municipal waste combustors and for hospital/medical/infectious waste incinerators by December 2000.	**COMPLETED.** U.S. EPA has promulgated regulations controlling emissions of mercury and other Hazardous Air Pollutants from municipal waste combustors (MWCs) and Medical Waste Incinerators (MWIs). Large MWCs needed to be in compliance by December of 2000, while small MWCs will need to comply by December of 2005, at the latest. Compliance was required at MWIs by September of 2002.	U.S. EPA
Canadian federal, provincial and territorial governments to investigate the release of mercury to the environment from various commercial products and some forms of wastes. Focus on dental amalgam, fluorescent lamps and sewage sludge. Expected to result in Canada-wide standards.	**COMPLETED**. See section 5.5 "Mercury Reduction Progress". Ontario passed Existing Hospitals Regulation (O. Reg. 323/02) requiring all existing hospital incinerators to close by Dec. 6, 2003. Ontario Regulation 196/03 came into effect Nov. 15, 2003 requiring all dental offices in which dental amalgam is placed, repaired, or removed to have a properly installed dental amalgam separator.	EC, MOE
Ontario Ministry of the Environment and EC to work with Ontario Dental Association to develop a "best management practices" document for dentists.	**COMPLETED** in 2002/03 in partnership with dental profession associations and regulatory bodies, dental collages and university and provincial and municipal governments.	MOE, EC
Information - Locally Based		
State University of New York at Buffalo: A Mercury Screening Model for Lake St. Clair: This grant supported the development of a model for the state and transport of mercury in Lake St. Clair, where mercury is a well documented problem.	**COMPLETED.** Project Period: 9/1/99 to 2/28/01.	U.S. EPA
Ohio EPA established the Ohio Mercury Reduction Group in 2001 to reduce the use, release, and emission of mercury in Ohio, to evaluate relevant departmental mercury programs and regulations, collect and assess data, promote the use of mercury alternatives and the collection of retired mercury and products, and educate industry, government and the general public on ways to reduce the sources of mercury in Ohio.	OMRG meets on a monthly basis and has produced fact sheets, an educational video, sponsored thermometer exchanges, shares the latest mercury information, and is working with U.S. EPA on their spill prevention guidance. Along with release of the guidance, OMRG will be working with U.S. EPA to educate every health department in Ohio on mercury spill and P2 information.	Ohio EPA
Information - Lake Erie Basin		
Report on an annual basis, the status of sediment remediation at priority sites within the Lake Erie basin.	See Binational Toxics Strategy Annual Report at www.binational.net	U.S. EPA and EC

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
If on-going long-range sources of mercury to the Great Lakes are confirmed, work within international frameworks to reduce releases.	In 2003, the United Nations Environment Programme (UNEP) established the new global Mercury Programme. Both Canada and the United States are participating in the Mercury Programme, which has urged all countries to adopt goals and take actions, as appropriate, to identify populations at risk and to reduce human-generated releases. The UNEP Mercury Programme will provide capacity building and technical assistance to help countries better characterize and address their mercury problems. The U.S. EPA and Environment Canada, with the support of the Commission for Environmental Cooperation, the International Joint Commission, and the Delta Institute, held a workshop on the long-range transport of toxic substances to the Great Lakes. The commissioned background paper, the workshop's program, the workshop presentations, and the draft summary document are available on the Internet at: http://www.delta-institute.org/lrtworkshop/open.html.	U.S. EPA and EC
Develop a pollution prevention web page at www.deq.state.mi.us/ead/p2sect/mercury and distribute mercury outreach materials to science teachers.	**COMPLETE.** The Michigan Department of Environmental Quality's (MDEQ's) environmental coordinator conducted a mass mailing of Pollution Prevention (P2) materials to all Michigan Intermediate School Districts. The "Science Teachers" and "Merc Concern" brochures were featured, along with a new publication titled "The P2 Education Tool Box".	Michigan and U.S. EPA
Lake Erie Public Forum targeted fish advisory materials and website in cooperation with the Lake Erie Binational Public Forum.	The Lake Erie Public Forum created easy to read and culturally sensitive fish advisory brochures to reach at risk populations. They were distributed at events likely to be frequented by minorities or lower income target populations. Information is also available on the Lake Erie Forum website, maintained by the Delta Institute, at www.erieforum.org/fishguide/fishguide.php. This project is ongoing.	Lake Erie Forum
EPA Superfund commits to completing maps including data on location of sensitive species, tribal lands, natural areas, managed lands, economic resources and potential spill sources and providing these maps to LaMP/RAP partners by the end of FY 2002.	Maps were completed for western Lake Erie and the Cleveland area. They are part of the Inland Area Sensitivity Atlas prepared as required under the Oil Pollution Act of 1990. See www.umesc.usgs.gov/epa_atlas/overview.html	U.S. EPA
Promote the Great Art for Great Lakes Virtual Classroom, with its mercury millennium theme, in primary schools in the Lake Erie basin.	**COMPLETE**	
Promote to school boards in the Lake Erie basin a mercury stewardship school curriculum program.	Project materials and workshops were delivered in over 20 schools across the Thames Valley District School Board and London District Catholic School Board.	EC
Information - Great Lakes Basin		
Ohio 's Office of Pollution Prevention will produce two fact sheets that focus on ways to reduce mercury and other PBTs.	Ohio EPA has produced 4 mercury fact sheets, a mercury web page and a mercury educational video. www.epa.state.oh.us/opp/mercury_pbt/mercury.html	Ohio EPA
U.S. Navy, Great Lakes Naval Station, Naval Dental Research Institute: Mercury Removal from the Dental-Unit Waste Stream – The interagency agreement provides funds to the Naval Dental Research Institute to examine the mercury removal from dental unit wastewater stream. Project Period: 9/1/99 to 8/31/00.	**COMPLETE.** The Great Lakes Naval Dental Research Institute continues to pursue this research with funding from U.S. EPA's Great Lakes National Program Office.	U.S. EPA

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
The Delta Institute Sector Based Pollution Prevention – The Delta Institute will focus on achieving reductions through commitments from the private and public sector owned and operated energy production units. Project Period: 10/1/99 to 9/30/00.	In July of 1999, the Delta Institute launched a partnership with the Council of Industrial Boiler Owners to achieve emission reductions of GLBTS Level I and Level II pollutants from industrial boilers through the implementation of selected energy efficiency technologies and methods. Delta undertook a study that found that a 10% improvement in energy efficiency to the 1531 coal burning industrial boilers and 1436 residual fuel oil burning boilers in the Great Lakes basin would result in a mercury emissions reductions of 443 lbs and 389 lbs respectively. Delta and CIBO are working with EPA, MDEQ and Ohio EPA to launch a national energy efficiency campaign for industrial boilers. More information can be found at http://delta-institute.org/pollprev/ibp.php	U.S. EPA
National Wildlife Federation: Local and sector based Pollution Prevention in the Binational Strategy – The National Wildlife Federation will focus on 1) building one existing efforts to implement pollution prevention, by way of sector-based strategies; and 2) coordinated environmental non-governmental organization participation in the Binational Toxics Strategy. Project Period: 10/1/99 to 9/30/00.	**COMPLETE.** NWF continues to participate in the GLBTS and pursue this work.	U.S. EPA
Ohio Healthy Hospital Pollution Prevention Initiative	A formal agreement was signed between Ohio EPA and the Ohio Hospitals Association in 1999 to develop and implement a strategy to virtually eliminate and OHA mercury and mercury-containing waste from the health care industry's waste stream by 2005. A mercury challenge handbook has been prepared as well as a web page and the program continues. See: www.epa.state.oh.us/opp/hospital.html	Ohio EPA
U.S. EPA will assist utilities in developing mercury control technology. Assistance may may not take the form of funding.	U.S. EPA and the Department of Energy have participated in several projects to develop "clean coal" technology.	U.S. EPA
Agencies will work with communities to provide sector-specific pollution prevention outreach such as workshops for the medical and dental communities, and other important sectors.	**Canada:** Online pollution prevention information to assist health care professionals is available at www.c2p2online.com Seminars on environmental programs, products and services were held during the Ontario Hospital Assoc. convention November 2002. Mercury thermometer take-back programs held at hospitals associated with the Cdn Coalition for Green Health Care. Green Healthcare workshop held in September 2003. **U.S.:** Chlor-alkali industry, through the Chlorine Institute, committed in 1996 to reduce mercury use 50 percent by 2005. The industry reported in April 2003 that they achieved 50% reduction in mercury use between 1995 and 2002. The American Hospital Association and U.S. EPA through the Hospitals for a Healthy Environment (H2E) program have produced a Mercury Virtual Elimination Plan for U.S. hospitals. In addition, workgroups are implementing work plans on various aspects of hospital waste reduction. U.S. EPA and Environment Canada held a workshop on dental mercury reductions for state and local governments in December of 2002. A report was produced, based on this workshop.	EC U.S.EPA

Committed Action (2000 LaMP)	Status (2004)	Lead Agency
U.S. EPA will encourage proper management of dental wastes that contain mercury.	U.S. EPA continues to fund dental mercury waste projects through the GLNPO Pollution Prevention and Toxics Reduction grant program and Regional PPIS grants. A grant was awarded to Erie County (NY) in 2003. A grant was awarded to Delta Institute to work with the cities of Solon and Elyria (OH) to reduce the input of mercury from medical and dental sectors into the waste stream of wastewater treatment plants. The project is ongoing.	U.S.EPA
U.S. EPA will track the disposition and of the U.S. Federal Government's mercury stockpiles.	**COMPLETE.** U.S. EPA has tracked the Defense Logistics Agency's development of an Environmental Impact Statement on the mercury stockpiles, which has been released in draft form. DLA has proposed a preferred option of long-term storage of the stockpile.	U.S.EPA
Agencies will assist schools in seeking out and disposing of mercury on school property.	The Michigan Department of Environmental Quality's (MDEQ's) environmental coordinator conducted a mass mailing of Pollution Prevention (P2) materials to all Michigan Intermediate School Districts. The "Science Teachers' and "Merc Concern" brochures were featured, along with a new publication titled "The P2 Education Tool Box".	U.S.EPA and Michigan
The Great Lakes Binational Toxics Strategy should be pursued to meet the short term, interim goals (e.g., 50% reduction in mercury U.S. sources and emissions by 2006 and for Canada, a 90% reduction in the release of mercury from polluting sources by 2000).	See Section 5.5 portion titled "Mercury Reduction Progress" and "Current Focus of Mercury Reduction Efforts."	U.S.EPA and EC
Sampling will begin in 2000 for the National Study of Chemical residues in lake fish tissue, a new effort to develop a national picture of the distribution of a variety of potential fish contaminants in the Nation's lakes. Bioaccumulative organic chemicals and mercury will be analyzed.	Sampling has been completed and a final report is due out by the end of FY2004.	U.S.EPA Region 5
U.S. EPA will complete the pilot projects to establish TMDL allocations for two waterbodies receiving mercury from atmospheric deposition in order to evaluate the integration of air and water program technical tools and authorities and to examine emission reduction options.	U.S. EPA Headquarters is currently reviewing a proposal from the ECOS Quicksilver Workgroup on developing alternatives to TMDLs for mercury. Once the proposal is finalized, Region 5 will be working with states to develop either this alternative or to develop TMDLs.	U.S.EPA Region 5

5.6 Emerging Chemicals

The LaMP has recognized that emerging chemicals may impact on the LaMP's vision of a sustainable Lake Erie ecosystem and that a process is needed to evaluate the potential impacts, sources, and remediation options for emerging chemicals. The LaMP will be looking to the Great Lakes Binational Toxics Strategy, as the experts in persistent toxic substance reduction, to identify potential emerging chemicals of concern in the Great Lakes. The Great Lakes Binational Toxics Strategy has committed to developing an *Emerging Pollutants Evaluation Protocol* to evaluate the impacts of specific emerging pollutants in the Great Lakes.

The LaMP's Sources and Loads Subcommittee anticipates updating the list of critical pollutants and pollutants of concern over the next two to three years. A review of the beneficial use impairments (BUIs), together with information about the potential causes of those BUIs, will be used to assess whether changes in status of the existing pollutants of concern and/or critical pollutants are warranted, or whether new compounds should be elected to these lists.

5.7 Future Directions

The binational sediment mapping of critical pollutants and pollutants of concern has been completed (see Section 5.2). A report is in preparation by the U.S. Geological Survey (USGS) outlining the methodology and results of the sediment mapping initiative, including an overview of contaminated sites in the basin, an assessment of spatial trends, and recommendations for future directions in the management of contaminated sediments. The report will also include a summary of the findings of the sediment workshop held in 2002 in which experts from across the basin met to discuss the status of sediment contamination, assessment and remediation projects in the Lake Erie basin.

Through the United States Geological Survey, the Sources and Loads Subcommittee is also currently undertaking a basin-wide initiative to map fish tissue contaminant data, similar to the sediment mapping effort. Fish species that migrate over relatively small areas are being selected so that spatial trends can be assessed in a meaningful way across the Lake Erie basin. Possible relationships in the spatial trends between the fish tissue and sediment quality data will be examined. Differences between the different agencies' fish collection procedures and analytical methods may make some data comparison difficult, but it is anticipated that this information compilation will result in a unique, basin-wide view of the status of fish contamination. A report of this initiative is anticipated during 2004.

In addition to providing technical reports of the results of the mapping initiatives, we anticipate some more informal reporting to the Remedial Action Plans (RAPs) to proceed during 2004. The RAPs may be interested to know how the contaminant status within their particular area of concern (AOC) compares with other AOCs. As a communication tool, the Sources and Loads Subcommittee will also be calculating a Sediment Quality Index (SQI) for the sediment quality data across the basin. The SQI compares the sediment quality data to existing environmental guidelines, and is used to calculate an overall index that rates the sediment quality as excellent, very good, good, fair or poor. In this way, the overall sediment quality can be viewed in a nutshell, across the basin, without having to assess information from the maps of the sediment quality compounds individually.

An analysis of source information in the basin will form the next priority for this Subcommittee. Both the U.S. and Canadian environmental agencies compile and maintain information about discharges of contaminants to the environment. The available information will be compiled on a binational basis and compared with the environmental quality information already examined in order to assess if monitoring gaps exist (e.g., sources with no nearby monitoring data) or if there are sites of unexplained environmental quality (e.g., hot spots with no known sources). The Subcommittee is also aligning itself to better coordinate with the Great Lakes Binational Toxics Strategy (GLBTS) in order to follow up on source reduction activities and remediation activities.

5.7.1 Evaluation of Pollutant Release Inventories and Permit Systems

Over the next year, the Lake Erie LaMP Source and Loads Subcommittee will be evaluating national datasets that provide estimated and measured releases of critical and priority pollutants within the Lake Erie Basin. The Toxic Release Inventory (TRI) and the Permit Compliance System (PCS) will be evaluated in the United States, while the National Pollutant Release Inventory (NPRI) and Ontario's Municipal/Industrial Strategy for Abatement (MISA) will be evaluated in Canada.

Although useful in many ways, the TRI and NPRI have various limitations and do not capture data for all substance releases into the basin. In particular, the criterion for reporting to these programs is such that numerous smaller sources are not captured. Also, reported releases are not always measured, but may in fact be estimates. Reporting criteria have evolved over the years, requiring new sectors to report; substances have been added or reporting thresholds for existing substances have changed. These ongoing changes make it more difficult to interpret the overall database through time. The data that is of greatest value to the Lake Erie LaMP are the on-site releases to air, water, and land, as well as off-site transfers of substances to sewage treatment plants. Releases to land include those contaminants disposed on-site to sanitary or hazardous waste landfills, as well as land surface applications and holding pits. Releases reported within the Lake Erie Basin do not necessarily imply that they are directly discharged to Lake Erie, nor that these contaminants are physically or biologically available to biota within the Basin; however, it is an adequate representation of sources and releases of available or potentially available contaminants.

Figures 5.11 and 5.12 show the top 10 contributing industries for releases of mercury and mercury compounds to land (including on-site landfills), off-site transfers to sewage treatment plants, and releases to air and water, respectively, over an eight year period (1995-2003) within the Lake Erie Basin. During that period, over 69,000 kg (151,800 lbs) of mercury were reported released or transferred to the basin: approximately 29,200 kg (64,000 lbs) to sewage treatment; 19,900 kg (43,780 lbs) to air, 20,000 kg (44,000 lbs) to land, and 168 kg (370 lbs) directly to water. Companies certified to deal with sanitary and hazardous waste were the top contributors followed by electric generating plants and chlor-alkali plants. Other contributors were manufacturers of industrial chemicals, paper, steel, mineral products, electric lamps, hoses and belts, and cement.

Figures 5.13 and 5.14 show the top contributors of PCBs to the environment as reported by TRI over the same eight year period. The NPRI program in Canada does not require reporting for the release of PCBs. Over 758,000 kg (1.7 million lbs) of PCBs were disposed of at on-site hazardous waste landfills and storage facilities within the Basin, representing 99% of the total PCBs released. Five kg (11 lbs) were released to sewage treatment, and 310 kg (680 lbs) were released to the air. No PCBs were reported discharged directly to water. As was the case for mercury, waste management companies were the top contributors as a secondary handler of PCBs transferred from other facilities for the purpose of treatment/disposal. Manufacturers of abrasive products were the greatest contributor of PCBs to the air with 160 kg (352 lbs).

A detailed summary of the bed-sediment, related fish tissue and industrial emissions data analyzed for use in the LaMP 2006 report will be published by USGS in 2007.

Figure 5.11: Mercury and its compounds - Top 10 industries reporting onsite releases to land and transfers to sewage treatment plants within the Lake Erie Basin. (Toxic Release Inventory (TRI) and National Pollutant Release Inventory (NPRI), 1995-2003)

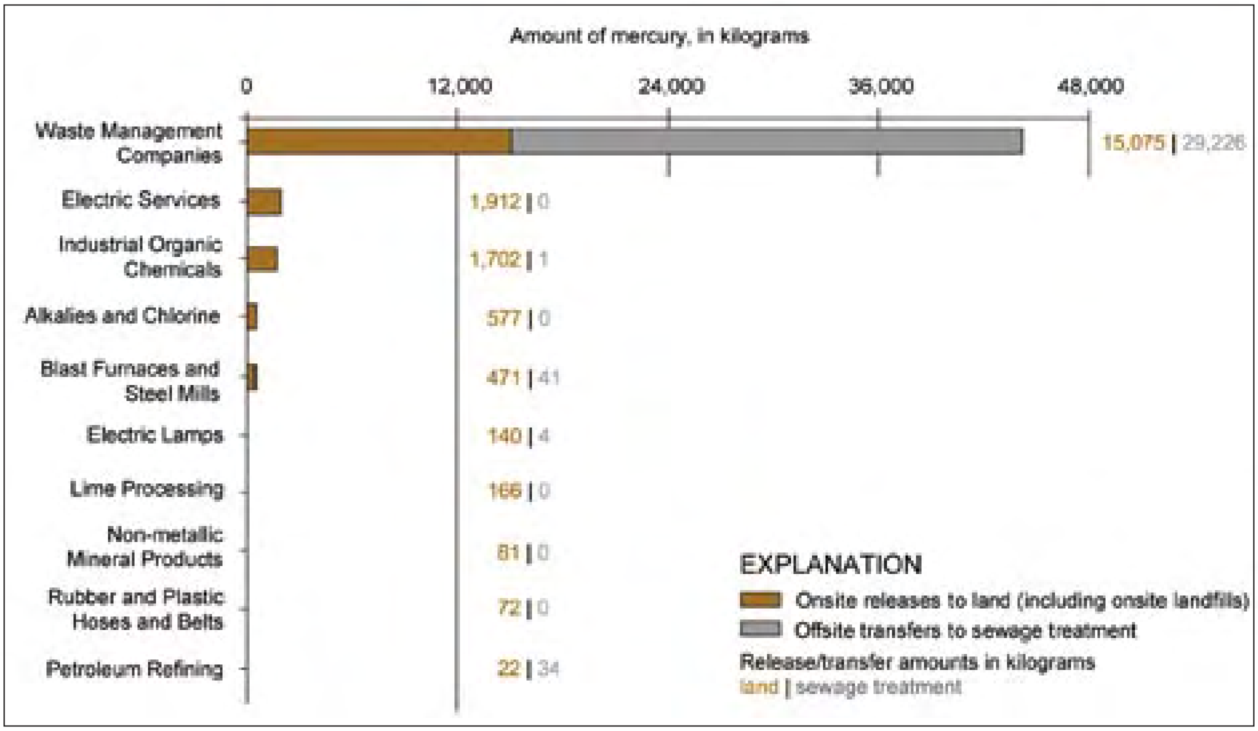


Figure 5.12: Combined estimated mercury onsite releases to air and water within the Lake Erie Basin for the top 10 contributing U.S. and Canadian industries. (Toxic Release Inventory (TRI) and National Pollutant Release Inventory (NPRI), 1995-2003)

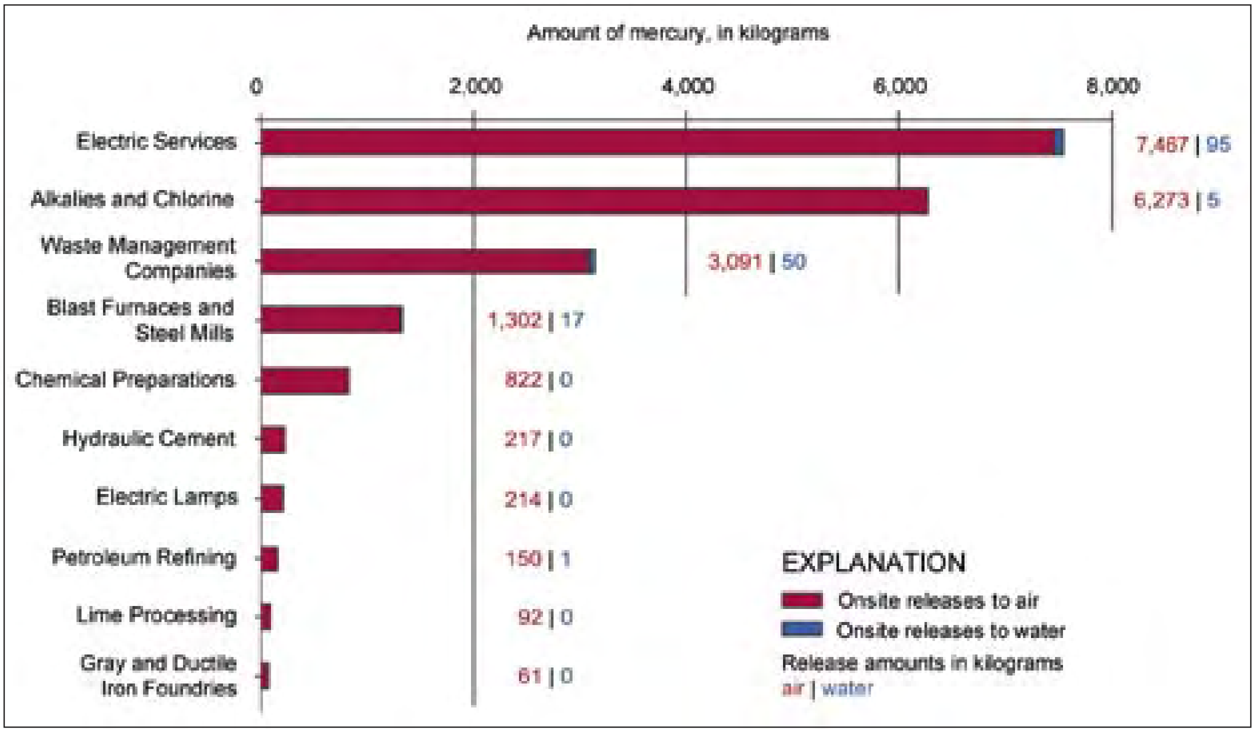


Figure 5.13: Polychlorinated biphenyls (PCBs) - Industries reporting onsite releases to land and tranfers to sewage treatment plants within the Lake Erie Basin. (Toxic Release Inventory (TRI), 1995-2003)

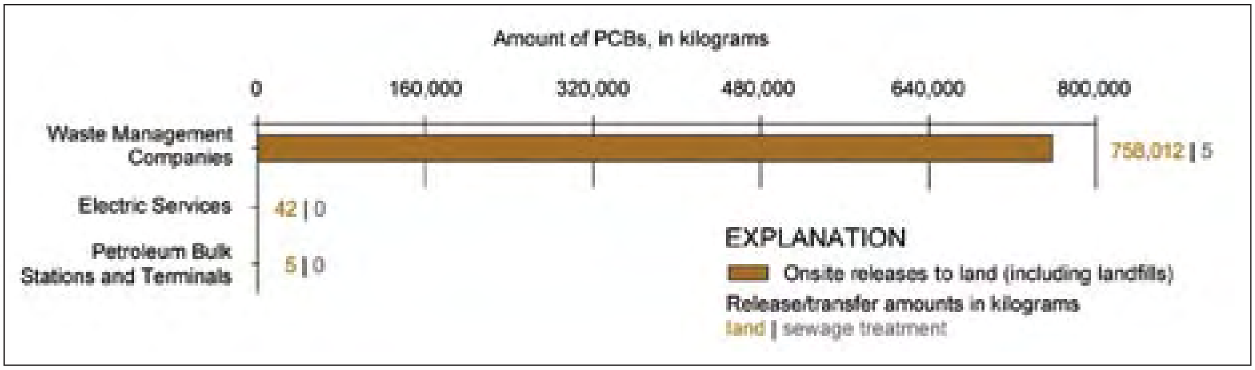
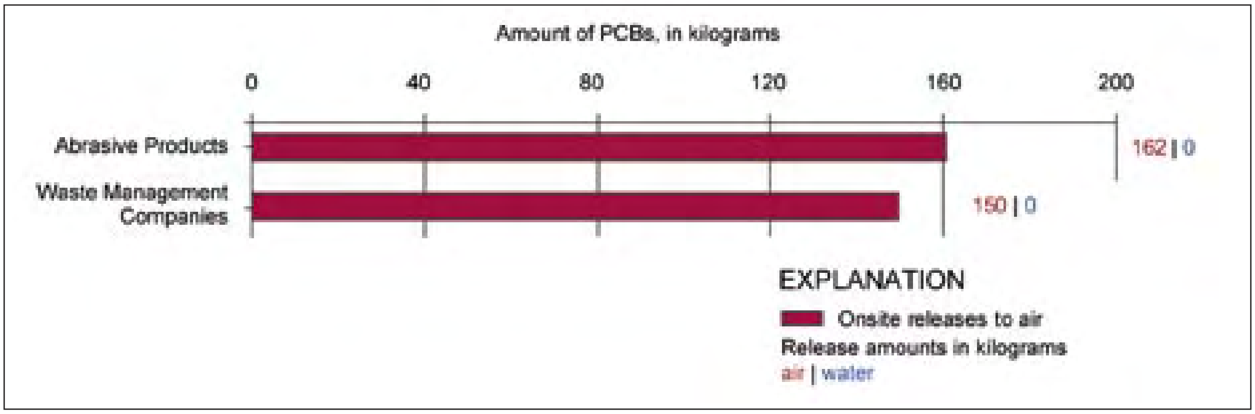


Figure 5.14: Polychlorinated biphenyls (PCBs) - Industries reporting onsite releases to air and water within the Lake Erie Basin. (Toxic Release Inventory (TRI), 1995-2003)



5.8 References

Canadian Council of Ministers of the Environment (CCME), 1999: Canadian Environmental Quality Guidelines. Winnipeg, Manitoba.

Dove, A., S. Painter and J. Kraft, 2002: Sediment Quality in Canadian Lake Erie Tributaries: A Screening-Level Survey, Ecosystem Health Division, Ontario Region, Environmental Conservation Branch, Environment Canada, Report No. ECB/EHD-OR/02-05/I

Helsel, D.R., and R.M. Hirsch. 1993. Statistical Methods in Water Resources, Studies in Environmental Science 49: Elsevier, New York. 276 p.

Ingersoll, C.G., D.D. MacDonald, N. Wang, J.L. Crane, L.J. Field, P.S. Haverland, N.E. Kemble, R.A. Lindskoog, C. Severn and D.E. Smorong, 2000: Prediction of Sediment Toxicity Using Consensus-Based Freshwater Sediment Quality Guidelines. U.S. Geological Survey final report to U.S.EPA, Great Lakes National Program Office. EPA 905/R-00/007.

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000a. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology 39:20-31.

Painter, S., D.N. Meyers and J. Letterhos, 2000: Characterization of Data and Data Collection Programs for Assessing Pollutants of Concern to Lake Erie, Lake Erie Lakewide Management Plan (LaMP) Technical Report Series, June 2000.

Painter, S., C. Marvin, F. Rosa, T. Reynoldson, M. Charleton, M. Fox, P.A. Thiessen and J.F. Estenik, 2001: Sediment Contamination in Lake Erie: A 25-Year Retrospective Analysis. Journal of Great Lakes Research Vol.27(4):434-448.

Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Toronto, Ontario Ministry of Environment and Energy, 24 p.

Shelton, L.R., and P.D. Capel, 1994: Guidelines for Collecting and Processing Samples of Stream Sediment for Analysis of Trace Elements and Organic Contaminants for the National Water Quality Assessment Program, United States Geological Survey Open-File Report 94-458, Sacramento, CA,U.S.A.

Smith, S.L., MacDonald, D.D., Keenleyside, K.A., Ingersoll, C.G. and L.J. Field, 1996: A Preliminary Evaluation of Sediment Quality Assessment Values for Freshwater Ecosystems: Journal of Great Lakes Research, Vol. 22(3):624-638.

Section 6:Habitat

Photo: Scott Gillingwater

6.1 Introduction

The Lake Erie LaMP has identified habitat loss and degradation as one of the top three stressors that must be addressed to restore Lake Erie. The alteration of natural lands through the loss of forests, wetlands, grasslands, and changing hydrology has had marked effects on biotic processes and fish and wildlife populations in the Lake Erie basin.

The Lake Erie LaMP beneficial use impairment assessment found fish habitat in Lake Erie tributaries, coastal wetlands and nearshore areas to be impaired. Over 80% of historical coastal wetlands have been lost and most of those remaining are diked or have degraded physical or chemical properties. All 15 of the general habitat types representative of, and inextricably tied to, the aquatic components of the Lake Erie environment are impaired within at least one Lake Erie basin jurisdiction. Degradation of 14 of these habitat types are resulting in unmet wildlife population management objectives for particular wildlife species. Upland marsh, wet meadow, emergent macrophyte, bog/fen and interdunal wetlands are the five most commonly degraded habitats responsible for this problem. Benthic habitats in the lake have also been lost or disturbed. The loss of chironomid larvae and benthic invertebrate diversity in Lake Erie tributaries indicates that these habitats are also degraded.

In addition to loss of habitat, the beneficial use impairment assessments identified the loss of ecological function, or how efficiently the habitat supports the biological community that inhabits it. For example, dams prevent fish from swimming upstream to spawn; dredging and/or filling wetlands create avenues for non-native invasive species, such as purple loosestrife, to take hold and proliferate, greatly reducing the nutritional value provided by the wetland. Ecological function is impaired not only because of outright habitat destruction, but also because of anthropogenic activities that have increased sediment loads, raised soil and water temperatures, and altered river flows and hydrology. There is a direct connection between land use, nonpoint source runoff and habitat quality.

In order to address the key issue of habitat loss and alteration, the Lake Erie LaMP 2000 document sought to present a habitat action plan. With the emphasis on "action", the LaMP 2000 report focused on identifying ongoing or planned projects that would preserve habitat or restore impairments and serve to meet the ecological objectives of the LaMP.

There are already a large number of habitat projects underway around the basin by a variety of agencies and local groups. Considerable review suggested there was a larger need for strategic planning rather than just listing and prioritizing projects for implementation. It is the LaMP's role to determine what it can best do, from a value added perspective, to tie existing efforts together and address gaps to see impacts/results on a lakewide basis. So LaMP efforts focused on developing a habitat strategy.

The habitat strategy developed for the Lake Erie LaMP provides a framework to guide and coordinate habitat protection and restoration efforts in the Lake Erie basin. The focus of the habitat strategy is on habitat preservation, restoration and improving the ecological function of habitats. It also considers the preservation, restoration and enhancement of the ecological processes that create and maintain habitats. The LaMP recognizes that implementation of the habitat strategy will be done largely through linkages with already existing programs. A number of these programs are referenced in the beneficial use impairment assessment reports addressing habitat and in the habitat section of the LaMP 2002 report. Others are mentioned at the end of this chapter. It is most important to remember that this habitat strategy was developed so LaMP partner agencies can incorporate these ideas into their own agency programs to better direct/redirect their programs to influence habitat quality around the Lake Erie basin and to be more in line with the goals of the Lake Erie LaMP.

The Habitat Strategy is presented below.

6.2 Lake Erie LaMP Habitat Strategy

The loss and fragmentation of aquatic and terrestrial habitats is affecting ecosystem function in Lake Erie and its watersheds (Figure 6.1). The 1995 Lake Erie LaMP Concept Paper identified habitat loss and degradation as one of the three key stressors that must be addressed to restore Lake Erie. Several beneficial use impairment reports have also outlined impairments to terrestrial, tributary, shoreland/wetland, nearshore and offshore habitats that are affecting benthic invertebrate, fish and wildlife populations (Ciborowski in prep.; Halyk and Davies 1999; Lambert et al. 2001; Lake Erie LaMP 2000; Lake Erie LaMP 2002).

Recent results from a Lake Erie LaMP ecosystem objective modeling process have shown that land use is a key factor responsible for impairments to Lake Erie, along with nutrient loading, natural resource use (exploitation)/disturbance and contaminants. All of these factors need to be managed to protect, restore and rehabilitate habitats and their integrity in the Lake Erie basin. This strategy presents some key objectives that the Lake Erie LaMP partners are working toward over the next few years.

Guiding Principles

The habitat strategy for the Lake Erie LaMP must adopt a holistic program for conserving the biodiversity and ecological processes in both terrestrial and aquatic systems in the Lake Erie basin. Protection of natural habitats is the primary goal followed by habitat restoration and then habitat rehabilitation. Due to limited resources, funding efforts may focus on programs that will restore the integrity of aquatic systems in lake-effect habitat zones (e.g., lower reaches of tributaries) and Lake Erie proper. In moving forward with the habitat strategy and research on habitat issues, Lake Erie LaMP partners will adopt seven principles to conserve aquatic biodiversity adapted from Noss and Cooperrider (1994). LaMP agencies will use the guidelines and following objectives and actions in some priority (target) watersheds, monitor the success of this approach, and adapt the process if management actions are not having noticeable, positive impacts on Lake Erie habitats. The LaMP approach will build on existing habitat initiatives and seek to support areas where LaMP partner agencies have already directed habitat project funding. The hope is that the LaMP can show that these principles, if taken to heart by management agencies and management programs, can expedite positive change in Lake Erie basin habitats.

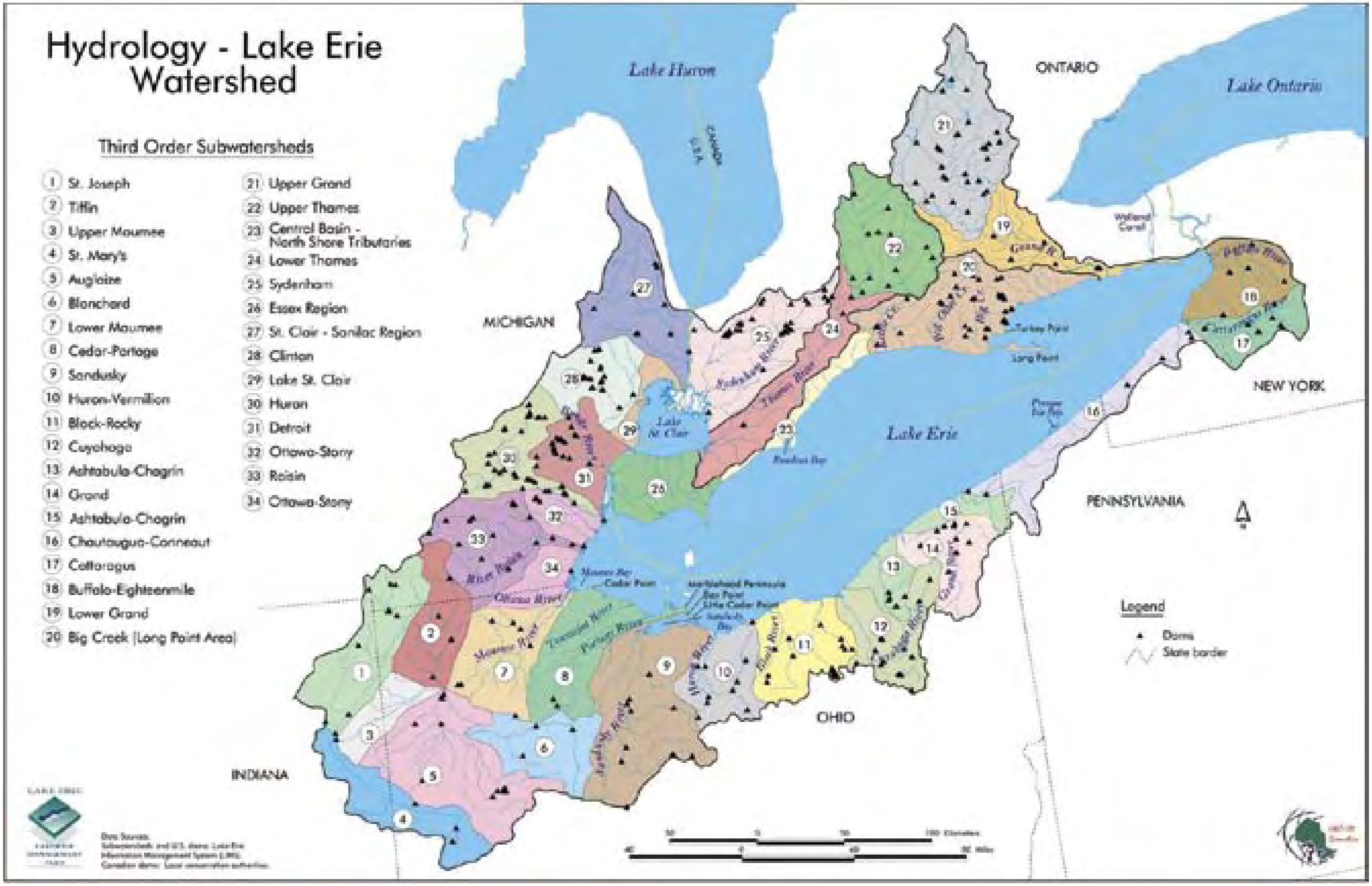


Figure 6.1: Hydrology of the Lake Erie Watershed

Lake Erie LaMP (updated April 2006)

1. **Scale** - Address aquatic and terrestrial issues at the proper scale of resolution (ecoregions and ecodistricts, ecological drainage units, watershed/subwatershed, etc.). Watersheds or hierarchical classifications of watersheds (e.g., tertiary, quaternary) are generally regarded as the proper units for aquatic system management. Gene and species level research on plant and animal populations within the Lake Erie basin is another valuable component that could be used to define scale. For example, a genetically unique population of walleye in the Grand River (ON) is being considered for management options in the watershed.

2. **Baseline** - The baseline for management should be pre-European settlement vegetation communities in terrestrial landscapes and historical flow patterns for aquatic systems. In some cases, guiding principles clearly reflect the ideal scenario that may never be achievable in a heavily human-influenced system such as Lake Erie. Restoration and rehabilitation efforts need to approximate original flow patterns, natural seasonal cycles, and continuous (i.e., un-fragmented) landscapes, wherever possible, to restore ecosystem processes and habitat function.

3. **Integrated management of land and water** - Better integration of aquatic and terrestrial ecosystem planning will be key to the success of the Lake Erie LaMP. The Lake Erie ecosystem objective modeling process (Colavecchia et al. 2000) showed that lake conditions largely result from human activities on land.

4. **Protected areas** - A well-dispersed network of protected areas (reserves) or habitat refugia with natural ecosystem features is needed to restore and maintain biodiversity. Habitat fragmentation effects and corridors should be considered in the selection and management of new protected areas. Although pristine conditions will no longer occur in many areas of the Lake Erie basin, the aim should be to restore areas and include them in protected area systems, wherever possible. Place priority on protection of areas of high native species diversity, species endemism, number of species at risk or species of management concern, and areas of critical importance to aquatic systems. Areas adjacent to these high priority areas would then receive secondary priority.

5. **Restoration goals and priorities** - Restoration should focus on restoring underlying habitat structuring processes and solving root causes of environmental problems (e.g., restoring hydrological function, migratory pathways). Work toward removing existing problem areas that may cause extreme damage to watersheds now or in the future. Problems could include contaminated sites and sites with high nutrient inputs (either due to agricultural runoff or insufficient wastewater treatment). Set priorities on activities that accomplish the most good for the least investment. Ensure that cost-benefit analyses be done at a larger scale (landscape, watershed) than just simply on a project-by-project basis. Take into consideration the cumulative effects of protection and restoration activities.

Photo: Scott Gillingwater

6. **Key threats to aquatic systems -**
   Dams and diversions - Avoid construction of new dams and diversions unless these structures provide a net benefit to the Lake Erie fish community such as in the management of non-native invasive species, or unless appropriate measures to mitigate fish community effects are included in the construction. Barriers are an important component in the control of non-native invasive species such as sea lampreys. Removal projects should address the implications of range expansion of non-native invasive species, impacts of changed hydrology, potential impacts from disturbed sediments, biodiversity, and overall benefits to aquatic systems.

   Non-native invasive species - Work toward prevention of future introductions of non-native invasive species in the Lake Erie Basin. Control or eliminate established non-native invasive species wherever possible.

7. **Address key and emerging information needs** - Inventory, monitor and conduct research to continue to conserve and restore terrestrial and aquatic biodiversity in the Lake Erie basin. Policy is needed to accommodate shoreline habitat protection and private interests related to the impacts from fluctuating lake levels and climate change.

Goals

1. Protect and maintain high-quality habitats and the ecosystem processes that sustain them in the Lake Erie basin. To help accomplish this, guide development practices and land use practices such that they maintain or minimize impacts to ecological processes.

2. Restore, rehabilitate, enhance and reclaim degraded habitats and impaired hydrological function in the Lake Erie basin. Emphasis will be placed on habitats in the lake-effect zone of tributaries influencing Lake Erie.

3. Continue to promote the recognition that non-native invasive species have negative impacts on habitats in the Lake Erie ecosystem. Work toward prevention of further introductions of non-native invasive species into Lake Erie. Work towards controlling and reducing, where feasible, existing non-native invasive species.

4. Develop an integrated framework that will result in a consolidated vision of habitat for Lake Erie by adopting a common, basinwide standard for classifying, mapping, evaluating, tracking, and valuing habitats, their key attributes, and their regulating factors.

General Objectives

Objective 1: Expand and improve connectivity and habitat function of protected areas network in Lake Erie Basin

Short term actions:
- Network with other groups to identify existing protected areas and possibilities for expanding the protected areas network.
- Identify existing special management zones/protection measures for lake use (e.g., boating, hunting and dredging restrictions) designated by all government agencies (i.e., federal, provincial, regional and municipal).
- Support opportunities for the establishment of appropriate conservation areas (e.g., National Marine Conservation Areas) in Lake Erie.
- Encourage protection of more natural areas in the Lake Erie basin.
- Determine research needs, information gaps, and additional programs to further habitat protection/restoration and improve habitat function through the Lake Erie Millennium Network.

- Encourage better management practices in landscapes containing natural areas or in buffer zones surrounding natural areas. Implement measures to address erosion and runoff, reduce nutrient loadings, and pesticide use in the basin.
- Establish more functional linkages between protected areas throughout the watershed, particularly in priority watersheds.
- Characterize submerged moraines such as the Norfolk moraine.
- Establish an emergency response framework to protect key habitats in the Lake Erie basin from development pressures and emerging issues (e.g., West Nile virus and potential larvicide/adulticide spraying in wetland habitats).

Longer term actions:
- Incorporate lake objectives for benthic, fish and wildlife habitat into other initiatives.
- Encourage adoption/implementation of any relevant Lake Erie LaMP indicators by groups and agencies working in protected areas management.
- Characterize other submerged moraines and other lake bed features in Lake Erie.

Photo: Upper Thames River Conservation Authority

Objective 2: Restore, rehabilitate or reclaim functional habitats and ecosystems

Short term actions:
- Identify and focus efforts on some pilot watersheds and work to ensure that management plans adequately address lake-effect zones of tributaries along with headwater and upper tributary sections. Target efforts in reaches of tributaries that will have the most benefit to the health of Lake Erie. Identify key actions needed in tributaries to improve ecosystem function (e.g., dam removal, habitat protection/restoration, modification of land use practices, etc.) and hold workshops to initiate action. Monitor before, during and after restoration.
- Prepare status reports for priority watersheds (if necessary) that outline the current status of the system, including headwater and upper reaches of the tributary. Encourage work in headwater areas if they are key contributors, although this will not be the focus of LaMP efforts.
- Identify and characterize the condition of priority habitats for restoration work. Determine where Lake Erie LaMP habitat priorities match or overlap with priorities and objectives of other habitat protection and restoration initiatives.
- Notify agency offices in the Lake Erie basin of LaMP habitat protection and rehabilitation priorities to encourage more funding for rehabilitation work. Review and evaluate grants, loans and other financial assistance programs to determine their current and potential impact on improving Lake Erie habitats.
- Identify any restoration and rehabilitation efforts already recommended or underway in the Lake Erie basin, particularly in priority watersheds. Provide input, from a Lake

Erie LaMP perspective, to habitat protection and restoration efforts in the 12 AOCs in the Lake Erie basin.

- Facilitate and encourage the adoption of sustainable land use practices in priority watersheds and throughout the basin. Hold local workshops to draw together communities and explain goals and targets of land use/habitat components of the Lake Erie LaMP. Network with individuals implementing federal, state/provincial agricultural improvement programs.
- Raise awareness of Lake Erie LaMP among member municipalities. Prepare a short (5-10 minute) presentation about the LaMP.

Longer term actions:

- Develop targets to work toward in terms of habitat and biodiversity protection in the Lake Erie basin through LaMP indicators process.
- Examine existing management strategies for tributaries in the Lake Erie basin, watershed/subwatershed management plans, and relevant policies and legislation for gaps that need to be addressed to meet Lake Erie LaMP habitat restoration objectives.
- Provide input to the RAP teams working on AOCs on the testing and outcomes of Lake Erie LaMP indicators.
- Protect habitats from further chemical contamination and encourage restoration of contaminated sites.

Objective 3: Prevent further introductions of aquatic and terrestrial non-native invasive species and reduce their impacts on habitat in the Lake Erie basin

Short term actions:

- Identify initiatives, policy/legislation, and remedial options available for aquatic and terrestrial non-native invasive species in the Lake Erie basin. Actively work toward development and implementation of legislation and policies protecting Lake Erie from further invasions.
- Publicize need for prevention of further non-native invasive species introductions by holding workshops and information sessions at key forums.
- Facilitate preparation of educational materials for the public and politicians.

Objective 4: Produce a binational map of the Lake Erie Basin

- Introduce an integrated, binational mapping system for the Lake Erie basin that identifies land use, habitat types, elements of species biodiversity, and key hydrological and physiographic features. This mapping system will harmonize existing spatial data in the Lake Erie basin and contribute information to setting restoration priorities for the Basin.
- Hold workshops to expedite the development of a binational map that can be used in setting priorities for habitat protection and restoration, monitoring change in habitat quantity and quality over time, and public education about the biodiversity of Lake Erie.
- Adopt habitat classification systems. Use standardized habitat zones and biologically defensible classifications that reflect functional use and interrelationships of each watershed and the Lake Erie basin as a whole.
- Incorporate biodiversity layers and physiographic layers and use to help in identifying areas for protection/restoration and monitoring change (ideally habitat improvements) over time.
- Attempt to classify Lake Erie and associated watersheds in terms of focal or refuge habitats, adjunct habitats, nodal habitats, source areas, and degraded habitats.
- Use elements of this map with information at the appropriate scale in land use zoning and setting restoration priorities across the Lake Erie basin.

Objective 5: Increase public awareness and involvement in protecting and restoring Lake Erie habitats

- Publicize information concerning habitat and biodiversity in the Lake Erie basin; protection, restoration and reclamation efforts; policies and regulations relating to biodiversity and key threats to biodiversity (e.g. non-native invasive species); and encourage public involvement in Lake Erie protection and restoration efforts.
- Develop and distribute brochures, CDs, and/or fact sheets for priority watersheds. Coordinate, where possible, with existing watershed, habitat stewardship or lake programs.
- Communicate habitat protection and restoration success stories in the Lake Erie basin. Link reporting with existing stewardship activities/programs first, wherever possible.
- Develop 4-6 page summary of broad-scale impacts of non-native invasive species on habitats in the Lake Erie basin.
- Catalogue existing habitat protection and restoration information, and put together a "habitat toolbox" for distribution.

Objective 6. Implement a monitoring strategy that tracks changes in habitat quality and quantity and measures the success of protective and restorative activities to improve our understanding of ecological function and, ultimately, the effectiveness of subsequent projects

Short term actions:
- Monitor progress in habitat protection and restoration on Lake Erie through existing programs and newly created programs.
- Use existing monitoring tools with relevance to Lake Erie habitat goals (e.g., habitat guidelines, documents setting conservation targets, etc.).
- Use combination of GIS-based tools and maps, decision-support systems, and selected indicators relevant to habitat and ecosystem function to evaluate progress in protecting habitats.
- Review adoption/implementation of habitat guidelines and natural heritage plans by municipalities in priority watersheds and elsewhere in the Lake Erie basin.

Longer term actions:
- Use indicators and targets developed by Lake Erie Millennium Network to monitor habitats and changing land use at the appropriate scale (e.g., watershed, subwatershed) and by various habitat zones and types.

Definitions

Habitat - The Lake Erie LaMP Habitat Strategy will use the following definition for habitat: "the dwelling place of an organism or community that provides the requisite conditions for its life processes" (SER 2002). Some attributes of habitat include:
- "The four basic necessities for wildlife (i.e., food, water, shelter, and space to survive) which are needed in sufficient supply and structural arrangement to meet an animal's life needs. Wildlife habitats vary over space, time and depending on the life cycle of individual species" (Lambert et al. 2001).
- "Specific locations where physical, chemical and biological factors provide life support conditions for a given species" (IJC 1989). This definition would include non-structural environmental factors such as light intensity, water temperature, dissolved oxygen concentrations, dissolved nutrients, turbidity, water mass movement or thermal regime.

Habitat structure and function - Structure and function can be examined from various perspectives, including productivity, efficiency, linked ecological processes, biodiversity and biological integrity (Halyk and Davies 1999).

Photo: Upper Thames River Conservation Authority

Ecological processes or **ecosystem functions** refer to the dynamic attributes of ecosystems, including interactions among organisms and interactions between organisms and their environment (SER 2002). **Ecosystem functions** can refer to those dynamic attributes that most directly affect metabolism, principally the sequestering and transformation of energy, nutrients and moisture (e.g., trophic interactions, mineral nutrient cycling, decomposition) while **ecosystem processes** refers to dynamic attributes such as substrate stabilization, microclimatic control, differentiation of habitat for specialized species, pollination, and seed dispersal (SER 2002).

Restoration - Process of working to return a habitat or ecosystem to its original (pre-settlement) state by removing the cause of degradation. Requires an understanding of the physical, chemical and biological processes within an area (e.g., watershed) while recognizing land uses that have caused structural and functional damage to the ecosystem. Goal is to re-establish the pre-existing biotic integrity in terms of species composition and community structure (SER 2002).

Rehabilitation - Process of working to recover natural functions, ecosystem processes, productivity and services within the context of the existing disturbance(s) (SER 2002).

Reclamation - Process to recreate the functions and processes of a naturally stable ecosystem with the understanding that it will be quite different from the condition prior to the disturbance. Main objectives of reclamation may include the stabilization of the terrain, assurance of public safety, aesthetic improvement, and usually a return of the land to a "useful purpose" (SER 2002). For example, a reclaimed area may be re-vegetated but this may involve the establishment of a limited number of only one or a few species (SER 2002).

Enhancement - Any manipulation of the physical, chemical, or biological characteristics of native habitat that improves its value and ability to meet specified requirements of one or more species. The manipulation changes the specific function(s) or the seral stage present. Examples include practices conducted to increase or decrease a specific function or functions for the purpose of benefitting species at risk and practices conducted for the purpose of shifting a native plant community successional stage. Enhancement does not encompass routine maintenance and management activities, such as annual mowing or spraying for unwanted vegetation (USFWS - http://southeast.fws.gov/partners/pfwdef.html).

Pilot or Target Watersheds (short term - next 5 years)

The LaMP approach for the habitat strategy is to target some key watersheds that are believed to have key linkages to habitat and biodiversity in Lake Erie, monitor and evaluate the success of this approach in these target watersheds, and determine whether this is a valid approach to use or whether another approach is needed. Factors influencing the selection of these watersheds include substantial impacts on habitat or biodiversity in Lake Erie proper; impacts that have been identified through LaMP beneficial use impairment assessment reports or other information collected through the Lake Erie LaMP process; a large drainage basin; efforts already underway in the watershed; funding and/or community support; and data availability.

1. Grand River, Ontario
2. Thames River, Ontario
3. Big Otter Creek, Ontario
4. Rondeau Bay, Ontario
5. Sydenham River, Ontario
6. Maumee River, Ohio
7. Cuyahoga River, Ohio
8. St. Clair River and Detroit River Corridor

(No ranking is implied in the listing above).

Criteria and Available Tools to Use to Select Other Target Watersheds (longer term - 5 years and beyond)

Other watersheds will be selected for protection and restoration efforts over the course of the Lake Erie LaMP. Criteria and tools that may be used to assist in the selection process of additional watersheds over the longer term will include, but not be limited to the following:

Criteria

- drainage area/volume, water flow (e.g., mean monthly flow)
- sediment input or loadings to Lake Erie (e.g., Rasul et al. 1999)
- destructive or habitat-altering adjacent land uses
- nutrient loads
- areas with habitat programs underway and community interest
- turbidity
- ecological sustainable water use
- biodiversity
- vulnerability of watershed to development, habitat degradation
- productivity

Tools

- Biodiversity Investment Areas (BIAs) - Nearshore Terrestrial Ecosystems (Mysz et al. 1998). This study selected Lake St. Clair/Detroit River, Western Lake Erie, Presque Isle and Long Point as shoreline BIAs based on ecological features and values.
- Biodiversity Investment Areas - Aquatic ecosystems (Koonce et al. 1998). This study selected 14 sites in Lake Erie and Detroit River as candidate BIAs; tributaries included Grand River, OH; Maumee River, OH; Old Women Creek estuary, OH; Sandusky River, OH; Spooner Creek, NY; St. Clair River delta, ON/MI; Sydenham River, ON; and Tonawanda Creek, NY. Criteria used included high productivity, high biodiversity and/or endemism, and significant contributions to the integrity of the whole ecosystem.
- Biodiversity Investment Areas - Coastal wetland ecosystems (Chow-Fraser and Albert 1998). This study selected BIAs based on wetland information; some of these were riverine wetlands such as Big Creek and Cedar Creek in Ontario.
- Great Lakes Shoreline Biodiversity Investment Areas (Reid et al. 2000). This study produced a composite ranking of shoreline units based on three key criteria: species

or communities of special interest; diversity of habitats, communities and species; and productivity and integrity.

- The Nature Conservancy - Great Lakes Ecoregional Plan/The Nature Conservancy of Canada - Conservation Blueprint.
- US 305(b)/303(e) lists and water quality reports listing impacted stream segments and causes.
- United States Environmental Protection Agency, Region 5, Critical Areas GIS project results.
- Decision support system for Lake Erie being prepared by the Great Lakes Basin Ecosystem Team. Designed to help select the most important areas for conservation.
- The Nature Conservancy's Ecologically Sustainable Water Management Framework (www.freshwaters.org/eswm/framework.shtml).
- Relevant indicators and thresholds produced from the Indicators Task Group for the Lake Erie LaMP.

6.3 An Integrated Habitat Classification System and Map of the Lake Erie Basin *(Prepared by: Dr. Scudder Mackey, University of Windsor)*

Funded by a grant from U.S.EPA-GLNPO to support the Lake Erie LaMP, this project will develop an integrated habitat classification system and binational map for the Lake Erie Basin. Specifically, the project will: 1) develop and implement a unified, consensus based classification of five Lake Erie habitat zones from data available in existing habitat mapping projects that are lakewide or Great Lakes basinwide in scale; and 2) develop a geospatial database that integrates classification systems at relevant scales into map layers and eventually into a single, integrated GIS habitat map. This project addresses the need for a unified, consensus based habitat classification system and inventory, which is a fundamental, necessary prerequisite to manage and conserve critical habitats and maintain ecological integrity within the Lake Erie basin. The integrated habitat map will be used to track improvements in fish and wildlife habitat quantity and quality resulting from preservation, conservation, and restoration efforts and to guard against further loss or degradation from land use alterations.

In early June 2005, an Experts' Workshop was held at the Franz Theodore Stone Laboratory on Gibraltar Island to identify existing geospatial datasets within the Lake Erie Basin and assess habitat classification schemes currently in use within the basin. Sub-groups were established to further identify geospatial datasets and explore classification schemes within five natural and semi natural habitat zones, including: terrestrial; inland aquatic; coastal wetland; coastal margin; and open water areas of the basin. These sub-groups reconvened in early 2006 to review and reach consensus on an integrated hierarchical habitat classification scheme based on recommendations from each of the habitat zone sub-groups. These experts will form the core of a Habitat Working Group that will continue to provide guidance to the project team during the testing and validation phase of the project where the classification scheme will be tested in two pilot watersheds – the Maumee River watershed in northwestern Ohio and the Grand River watershed in southern Ontario.

The project team will develop a strategy to revise and expand the classification scheme to the rest of the Lake Erie Basin and will also develop a binational habitat map data exchange website that will include links to geospatial metadata and habitat coverage in the basin. The Lake Erie habitat classification and mapping project will serve as a model for the development of a comprehensive basinwide habitat classification system and inventory for the entire Great Lakes Basin.

The project team is collaborating with other ongoing habitat assessment projects in the basin, including: a Great Lakes Fishery Commission-supported project through the University of Michigan's Institute for Fisheries Research to develop a comprehensive Lake Erie GIS to provide fisheries resource managers with comprehensive geospatial datasets; and, an ongoing U.S. Geological Survey Aquatic GAP project designed to evaluate the biological diversity of aquatic species and their habitats, and to identify gaps in the distribution and protection of these species and their habitats within the Great Lakes Basin.

6.4. Fisheries Related Habitat Projects *(Prepared by: Jeff Tyson, Ohio Department of Natural Resources and Elizabeth Wright, Ontario Ministry of Natural Resources)*

The Great Lakes Fishery Commission's (GLFC) Lake Committees and the Council of Lake Committees have recommended that fisheries habitat research, rehabilitation and restoration focus on four broad theme areas to effectively address achievement of each lake's fish community goals and objectives. Those broad themes identified include: 1) restoration of hydrological processes including flow regime and nearshore circulation patterns; 2) inventory and mapping of fish habitat conditions and reference environmental conditions; 3) restoration of suitable physical (substrate, temperature, submerged aquatic macrophytes), chemical (contaminants, pH, dissolved oxygen, total suspended solids), and biological (food web structure, trophic transfer) habitat; and 4) restoration of suitable connectivity. These broad theme areas complement the Lake Erie LaMP Habitat Strategy Objectives 2 (restore functional habitat), 4 (produce a binational map), and 6 (monitor changes in habitat quality and quantity). A total of 25 projects involving monitoring or evaluation of habitat, 9 projects that involve developing rehabilitation strategies, and 26 projects that involve habitat rehabilitation have been identified for Lakes Erie and St. Clair. All of these projects will impact fisheries habitat restoration either directly or indirectly. One project that directly addresses hydrological processes and fisheries habitat is the GLFC funded Huron-Erie Corridor (HEC) project, which is presented in Section 6.5.

Projects in progress or planned that address the LaMP Habitat Objectives 4 and 6 include an OMNR assessment of north shore coastal wetlands (Rondeau Bay) and a binational mapping initiative planned for Maumee River, Ohio and Grand River, Ontario. These initiatives seek to identify reference conditions in Lake Erie watersheds and lake effect zones, as well as coastal wetlands. These reference conditions will be used by agencies as a benchmark for habitat conditions and to track improvements in habitat quantity and quality resulting from preservation, conservation, and restoration efforts. The mapping initiative is presented in more detail in Section 6.3.

Projects that address LaMP Habitat Objective 2 – to restore functional habitats in the Lake Erie basin - include several implementation projects that are completed or are in the planning phase. Two projects completed by the Essex Region Conservation Authority and several partners, including Environment Canada, are the Fort Malden Shoreline Stabilization and Habitat Enhancement Project, and the McKee Park Habitat Enhancement Project. These projects created or enhanced shoreline habitat in the Detroit River AOC through soft engineering techniques. The Middle Harbor Fish Habitat Restoration Project in Ohio (ODNR, Division of Wildlife) is planned for 2006 and will target nearshore fish community restoration in a 400 acre connected coastal wetland. The project will restore lateral connectivity between Lake Erie and a coastal wetland, as well as promote the re-establishment of submerged aquatic vegetation using an island feature to reduce wind fetch and sediment resuspension.

Photo: Upper Thames River Conservation Authority

6.5 Huron-Erie Corridor System Habitat Assessment – Changing Water Levels and Effects of Global Climate Change *(Prepared by Dr. Scudder Mackey, University of Windsor)*

This project, funded by the Great Lakes Fishery Commission through the USFWS Restoration Act and sponsored by the Michigan Department of Natural Resources, will create a framework and design a process to systematically identify, coordinate, and implement binational aquatic and fish habitat restoration opportunities in the Lake Huron to Lake Erie Corridor (Huron-Erie Corridor, HEC). The project will be conducted within a context of long-term water-level regime changes resulting from direct anthropogenic hydromodification and/or potential effects of global climate change.

In 2005, the University of Windsor and the Ohio State University hosted three Lake Erie Millennium Network (LEMN) research needs workshops to provide guidance on current and future research needs and to develop a long-term strategy to identify and assess high-quality aquatic and fish habitats within the HEC. These Experts' Workshops brought together fishery biologists, aquatic ecologists, physical scientists (geologists, hydrologists), and resource managers to: 1) assess the adequacy of existing physical and biological datasets within the HEC system, identify gaps and prioritize additional habitat research/data collection needs (Workshop 3.01); 2) explore issues associated with developing and validating robust physical and ecological models to predict current and future locations of critical aquatic and fishery habitats within the HEC system (Workshop 3.02); and 3) apply existing data and models to a range of "transitional habitat" issues, including refinement of conceptual models of habitat succession, i.e. "step-stone" or transitional habitats and refugia (Saxon, 2003) associated with anticipated changing water-level regimes in the HEC (Workshop 3.03).

Three major environmental zones were identified based on hydrogeomorphic characteristics and dominant physical processes. These zones included: connecting channels and adjacent riparian areas; the St. Clair delta and adjacent wetland complexes; and nearshore, coastal margin, and open-water areas of Lake St. Clair. Critical data collection and research needs were identified, including the need for: 1) high-resolution bathymetry and substrate distribution data in nearshore/coastal areas of Lake St. Clair; 2) flow, circulation, and temperature distribution patterns - both daily and seasonal throughout the entire system; 3) the location and characteristics of active spawning habitats; 4) the seasonal distribution of larval fish, young-of-the-year, adult fish, benthic invertebrates, aquatic macrophytes, and species-at-risk; 5) the location, distribution, and stability of contaminated sediments; and 6) seasonal data on nutrient and contaminant loadings.

Workshop participants identified a critical need to develop an integrated 3-D hydrodynamic model that predicts flow and water levels in the connecting channels, the St. Clair delta, and circulation patterns and water levels in Lake St. Clair as a single hydrodynamic system. Also identified was the need to develop integrated ecological models for each of the three major environmental zones that predict changes in habitat distribution and response of aquatic/coastal margin vegetative communities and fish/benthic communities to altered flow and water-level regimes.

A long-term research strategy was developed that identifies the following critical research elements: 1) A historical comparison with current HEC system aquatic and fishery habitats, including habitat distribution, pattern and function; the degree of habitat alteration and the stressors that cause those alterations; and identification of potential habitat restoration and enhancement opportunities based on historical pattern and function. 2) The development of scenarios based on physical and ecological models that explore habitat impacts resulting from potential long-term changes in water-level regime, assess the potential degree of habitat alteration, and identify potential long-term management, protection, and restoration opportunities. 3) Development of tools and build capacity of key agencies, organizations, and institutions to identify and implement protection, restoration, and enhancement opportunities based on sound science as part of a long-term, binational fishery and aquatic habitat research and monitoring effort within the HEC system.

6.6 Ohio Aquatic GAP Update *(Prepared by Dan Button, U.S. Geological Survey)*

The Ohio Aquatic Gap Analysis Project was completed in 2005. The primary products are geospatial (GIS) databases depicting land stewardship, stream habitat types, and predicted distribution models for native fish, crayfish, and bivalves. An analysis of these data where then used to help identify potential high conservation-priority areas at the 14-digit hydrologic (HUC) sub-watershed level using species richness. Species richness is measured by enumerating the fish species rather than measuring their abundance. Seventy-five of the 504 (15%) sub-watersheds in the Lake Erie Basin were identified as having high potential for priority conservation. Thirty-seven of the 75 already have some conservation lands located within them. For both the Lake Erie and Ohio River Basins combined, results show that 22 fish species and two bivalve species have predicted distributions exclusive of GAP classified conservation lands. Surprisingly, nine of these fish species are considered rare, threatened or endangered in the State. A final report is in progress and expected to be published on the GAP Analyses Program web site in 2006 (http://www.gap.uidaho.edu).

6.7 References

Chow-Fraser, P. and D. Albert. 1998. Biodiversity Investment Areas - Coastal Wetland Ecosystems. Identification of “Eco-reaches” of Great Lakes Coastal Wetlands that have high biodiversity value. State of the Lakes Ecosystem Conference 1998. October 1998.

Ciborowski, J. In preparation. Degradation of Benthos. Lake Erie Lakewide Management Plan (LaMP) Technical Report Series.

Colavecchia, M., S. Ludsin, P. Bertram, R. Knight, S. George, H. Biberhofer, and P. Ryan. 2000. Identification of Ecosystem Alternatives for Lake Erie to Support Development of Ecosystem Objectives. Lake Erie Management Plan (LaMP) Technical Report Series. Ecosystem Objectives Subcommittee. Environment Canada and U.S. Environmental Protection Agency. September 2000.

Halyk , L.C. and D.H. Davies. 1999. Loss of Fish Habitat. Technical Report No. 16, Lake Erie Lakewide Management Plan (LaMP) Technical Report Series. November 1999.

International Joint Commission (IJC). 1989. Living with the Lakes: Challenges and Opportunities. A Progress Report to the International Joint Commission. Prepared by the International Joint Commission Project Management Team.

Koonce, J.F., C.K. Minns, and H.A. Morrison. 1998. Biodiversity Investment Areas - Aquatic Ecosystems. Aquative Biodiversity Areas in the Great Lakes Basin: Identification and Validation. State of the Lakes Ecosystem Conference 1998. October, 1998.

Lambert, L., J. Robinson, M. Shieldcastle, and M. Austen. 2001. Executive Summary: Degraded Wildlife Populations and Loss of Wildlife Habitat. Technical Report No. 5, Lake Erie Lakewide Management Plan (LaMP) Technical Report Series. September 7, 2001.

Lake Erie LaMP 2000. The Lake Erie Lakewide Management Plan. Prepared by the Lake Erie LaMP Work Group under the direction of the Lake Erie LaMP Management Committee. [J. Letterhos and J. Vincent, Eds.]. Environment Canada, Ontario Region and U.S. Environmental Protection Agency, Region 5.

Lake Erie LaMP 2002. The Lake Erie Lakewide Management Plan. Prepared by the Lake Erie LaMP Work Group under the direction of the Lake Erie LaMP Management Committee. [J. Letterhos, Ed.]. Environment Canada, Ontario Region and U.S. Environmental Protection Agency, Region 5.

Mysz, A., R. Reid, and K. Rodriguez. 1998. Biodiversity Investment Areas - Nearshore Terrestrial Ecosystems. State of the Lakes Ecosystem Conference. 1998. October, 1998.

Noss, R.F. and A.Y. Cooperrider. 1994. Managing aquatic ecosystems. Pp. 264-297 In. Saving Nature's Legacy: Protecting and Restoring Biodiversity. Island Press, Washington, D.C.

Rasul, N., J.P. Coakley and R. Pippert. 1999. Sedimentary environment of western Lake Erie: geologic setting, sediment distribution and anthropogenic effects. Pp. 57-74 *In* State of Lake Erie - Past, Present and Future (Munawar, M., T. Edsall and I.F. Munawar, eds.). Ecovision World Monograph Series. Backhuys Publishers, Leiden, The Netherlands. 550 pp.

Reid, R., H. Potter, M. DePhilip, and K. Rodriguez. 2000. Great Lakes Shoreline Biodiversity Investment Areas. Background Integration Paper. October 2000.

Richter, B.D., R. Mathews, D.L. Harrison, and R. Wigington. In press. Ecologically sustainable water management: managing river flows for ecological integrity. Ecological Applications.

Saxon, E.D. 2003. Adapting ecoregional plans to anticipate the impact of climate change, in: Groves, C.R. (editor), Drafting a Conservation Blueprint – A Practioner's Guide to Planning for Biodiversity: The Nature Conservancy, Island Press. p. 345-365.

Society for Ecological Restoration Science & Policy Working Group. 2002. The SER Primer on Ecological Restoration. www.ser.org.

Some Management Objectives/Strategies in the Lake Erie Basin

(This list of objectives and strategies includes those identifed in Lake Erie LaMP Beneficial Use Impairment reports or by experts on the Habitat Strategy Task Group or expert reviewers; it is not a complete list)

Binational

- Restoration of Regional Shorebird Reserve (Western Hemisphere Shorebird Reserve Network) in western basin (Detroit, MI to Huron, OH) and protection of staging and breeding habitats in at key shorebird migration sites such as Long Point, ON and Presque Isle, PA.
- Support the North American Colonial Waterbird Conservation Plan objectives relating to habitat for the Upper Mississippi Basin/Great Lakes Colonial Waterbird Conservation Region which includes Lake Erie basin
- Partners in Flight and Important Bird Area programs in priority watersheds or habitat types for Lake Erie LaMP habitat protection and restoration activities
- Great Lakes Fishery Commission - Lake Erie Fish Community Goals and Objectives which recognize preservation and restoration of habitat as 1 of 8 guiding principles important for the identification of fish community objectives for Lake Erie (available March 2003)
- Great Lakes Fishery Commission - Lake Erie Committee - Draft Environmental Objectives
- Great Lakes Fisheries Commission Habitat Strategy
- Lake Erie LaMP ecosystem objectives (in development)

- The Nature Conservancy and Nature Conservancy of Canada Great Lakes Ecoregional Plan
- Regional Climate Change Guidelines for the Great Lakes prepared by Ecological Society of America Concerned Scientists
- Hartig, J.H. 1993. A survey of fish community and habitat goals/objectives/targets and status in Great Lakes areas of concern (http://www.glfc.org/pubs/SpecialPubs/Survey1993.pdf)
- Remedial Action Plans for Lake Erie Areas of Concern

Canada

- Great Lakes Wetlands Conservation Action Plan - strategy to protect area and function of 30,000 ha of wetlands in Great Lakes Basin by 2020.
- Policy for the Management of Fish Habitat
- Decision Framework for the Determination and Authorization of Harmful Alteration, Disruption or Destruction of Fish Habitat, Department of Fisheries and Oceans, Habitat Management Branch. 1998
- Strategic Plan for Ontario's Fisheries
- Ontario Ministry of Natural Resources Five Year Plan for Rehabilitation of Eastern Basin Fisheries 2000-2004
- Conservation Authority Fisheries Management Plans (e.g., Grand River Fisheries Management Plan)
- watershed plan objectives

United States of America

- Habitat acreage objectives for restoration/acquisition of upland marsh habitat in Lake Erie Marshes Focus Area of NAWMP (Lake Erie basin in Ohio). This plan calls for enhancement and restoration of 7,000 acres of existing protected wetland habitat and acquisition or protection of 11, 000 acres.
- United States Fish and Wildlife Service Conservation of Great Lakes islands and coastal near-shore habitats initiative
- Partners for Fish and Wildlife Ohio - http://midwest.fws.gov/Partners/ohio.html - habitat restoration on private lands
- Ecologically Sustainable Water Management Framework, Freshwater Institute, The Nature Conservancy - http://www.freshwaters.org/eswm/framework.html
- Aquatic Life Use Attainment Criteria for Surface Waters (Ohio)
- Ohio Lake Erie Qualitative Habitat Evaluation Index (QHEI)
- Ohio Lake Erie Quality Index
- Ohio Lake Erie Protection and Restoration Plan
- Ohio Environmental Protection Agency Headwater Streams
- Ohio Coastal Management Plan Nonpoint Source Program
- TMDLs around the US shoreline of Lake Erie

Section 7: Public Involvement

Photo: Upper Thames River Conservation Authority

7.1 Overview

A major tenet of ecosystem management is continuous involvement of the public that is inclusive and respectful of all viewpoints and stakeholders. All the partners involved in the LaMP process have long been committed to an open, fair and significant public involvement process. The key to public support and the program's success is effective communication between the government agencies and the diverse population of the Lake Erie basin.

To keep the public apprised of progress in the LaMP, the U.S. and Canadian governments maintain a broad-based mailing list of the public interested in the LaMP progress or who are involved in other environmental activities in the Lake Erie basin. From time to time, information concerning the Lake Erie LaMP is sent to people on the mailing list to foster an active network of the public interested in Lake Erie-related environmental issues.

To provide another mechanism for public involvement, the U.S. and Canadian governments fund the Lake Erie Binational Public Forum (Forum). This diverse and active group serves many purposes ranging from developing and implementing outreach projects and initiatives to educate the general public about Lake Erie issues, to providing advice to the LaMP Work Group based on members' individual expertise and/or input from local constituents they may represent. The Forum works closely with the governmental representatives on the Lake Erie LaMP Work Group.

This chapter presents a report of current public outreach efforts, not necessarily a *complete one*. Ongoing public involvement is crucial to the success of the Lake Erie LaMP, and public participation, consultation, and comment are welcome at any time in the Lake Erie LaMP process.

7.2 Background and History

The original public involvement strategy for the LaMP was completed in April 1995. It described a three-tiered approach to involving the public. Tier I is the Lake Erie Public Forum, which is composed of members who are familiar with LaMP activities, who have the most active level of public involvement in the LaMP and who have direct contact with the Lake Erie LaMP Work Group. Tier II, the Lake Erie Network, is composed of individuals and groups who have expressed an interest in the LaMP by attending meetings and workshops or by commenting on documents, and who have requested additional information about the LaMP. They form the mailing list for the Lake Erie LaMP. Tier III is the general public, with members being unfamiliar with the Lake Erie LaMP.

The Public Involvement Subcommittee provides information to the media about ongoing binational and local LaMP activities as a way of keeping the general public informed. When actions and activities related to the Lake Erie LaMP warrant, the lead agencies issue press releases to specific media markets to facilitate media exposure. The public is also reached through the use of displays and handouts at third party meetings, such as the International Joint Commission's biennial meetings. Information is also available through the LaMP websites that are provided at the end of this chapter.

In 1995, a questionnaire was distributed assessing the knowledge and involvement level of all individuals on the mailing list. The information requested was used to develop a public involvement and communication program to build teamwork between citizens and government agencies involved in accomplishing the goals of the LaMP.

7.3 Public Involvement Activities

Ecosystem Objective Consultation

During the months of May and June 1995 the Public Involvement Subcommittee held four ecosystem objective workshops in Sandusky, Ohio; Dunkirk, New York; and in Simcoe and Leamington, Ontario. The government agencies used these workshops to solicit public input toward identifying the desired future uses, or ecosystem objectives, of the lake. These workshops served to bring members of the public together with agency representatives to direct Lake Erie LaMP efforts. These early workshops set the stage for what was to become a working group of concerned, involved residents of the Lake Erie basin who have joined together as the Lake Erie Binational Forum.

Building on the public workshops in 1995, an adaptive approach has been taken to consult with the public on the selection of a preferred ecosystem alternative. The Public Involvement Subcommittee first worked closely with a group of technical experts to create a method to communicate to the public how the LaMP's Ecosystem Objectives Subcommittee arrived at four viable scenarios (ecosystem alternatives) for Lake Erie's future state. Then, the Forum was consulted and adjustments made to assure that the explanation of the process could be simply presented and easily understood by the public. Once the Work Group selected a preferred Ecosystem Alternative, the Public Involvement Subcommittee sought the Forum's advice to develop a scripted presentation to explain how and why the Work Group chose this alternative. This presentation was used at a number of public sessions throughout the Lake Erie basin during late 2001/early 2002. These efforts have provided the Lake Erie Work Group and the Lake Erie Management Committee with valuable public input and insight.

Status Report and Update

In its support role to the Work Group, the Public Involvement Subcommittee assisted in the production and distribution of the *Status Report* in the spring of 1999. A companion piece, called *Update '99*, was written and produced as the main distribution document to inform people about the issues in, and availability of, the *Status Report*. The *Update* mailing also served as a vehicle for informing the public about the availability of the various Beneficial Use Impairment Assessment Reports that the committee is responsible for distributing. Since then, the *Update* has become a regular publication of the LaMP, appearing every second year.

Other Activities

In addition to the activities already mentioned, the Public Involvement Subcommittee was involved in a variety of outreach activities. These include the production of the following documents: 1) Fact Sheet giving an overview of Lake Erie LaMP development, printed in Fall 1995 and revised in November 1996; 2) Distribution of educational posters entitled *Lake Erie Fish and Fishery* and *Waterbirds of Lake Erie* that were developed by various United States and Canadian government agencies involved with the LaMP; and 3) Creation and distribution of bookmarks with the URL for the binational LaMP website. The Public Involvement Subcommittee also created a display to be taken to meetings to inform the public about the LaMP.

7.4 Lake Erie Binational Public Forum

The Lake Erie Binational Public Forum marked its tenth anniversary in September 2005 at a meeting in Port Stanley, Ontario. Ten years ago, the government agencies involved in the LaMP created the Forum, recognizing that public input is critical to the LaMP's success. The Forum is a unique group of interested stakeholders from Canada and the U.S., including: farmers, business people, scientists, educators, anglers, boaters, environmentalists, governmental officials, labour leaders, public health workers and others. These individuals have brought together their talents, interests and concern for Lake Erie, to provide input on the planning and implementation of the LaMP, and to foster effective two-way communication with the diverse population of the Lake Erie basin.

The work of the Binational Forum is primarily a voluntary effort, although some members have a direct link to the group because of their occupations. Members often drive several hours to attend Forum meetings, which are held two to three times a year on alternating sides of the border. Despite the time and distance involved, the majority of Forum members have remained active throughout the last decade, proving their interest and dedication.

The Forum has three main roles and functions including:

- playing a significant role in the LaMP process with real involvement and proactive initiatives;
- increasing stakeholder participation in the LaMP process; and
- facilitating and/or participating in Forum sponsored LaMP related activities at the local level.

In order to accomplish these three roles and functions, the Forum acts as a partner with governments and governmental agencies in goal setting and decision making; assists the Technical Subcommittees in drafting LaMP reports and reviewing Work Group documents; provides advice and input to the Work Group and Management Committee in developing and implementing the LaMP; and promotes the Forum's vision and goals for Lake Erie. Forum members are also committed to taking information from the LaMP back to the community in a form that can be understood by the public. In this capacity, Forum members provide a valuable link to thousands of stakeholders throughout the basin who they interact with in their professional and private lives.

Photo: Upper Thames River Conservation Authority

A highlight of the tenth anniversary meeting was the launch of the Forum's Lake Erie Lakewide Management Plan Implementation Project. In an effort to demonstrate Lake Erie LaMP implementation at the local watershed level, the Forum worked with partners from Kettle Creek, Ontario and Black River, Ohio to create community-based watershed strategies and build local capacity for ongoing ecosystem stewardship.

The purpose of the strategies was to:

- Prioritize environmental concerns of the local watershed communities;
- Identify activities to address these concerns that also complement the goals of the Lake Erie LaMP; and
- Build local frameworks for ongoing implementation of the identified activities.

As part of the strategy development process, the Forum identified common issues, or barriers, to improving water quality and watershed management in each of the case study watersheds with respect to land use, human health and emerging issues. Upon further research, many of the barriers identified in the case study watersheds were found to be common problems in other watershed communities throughout the Lake Erie Basin. The Forum subsequently developed a series of three reports, one for each topic area, that more broadly describes common concerns and provides recommendations to address those issues at the local and state level. The watershed strategies and the reports are available on the Forum's website: http://www.erieforum.org/watershedprojects.php.

By conducting this process concurrently in Canadian and U.S. watersheds, the Forum identified opportunities for communities around Lake Erie to apply the experience gained through this project and fostered increased local stewardship activities that benefit the basinwide ecosystem.

Evidence of the success of the implementation project was provided by Forum members from New York. These members introduced and gained Forum support for another implementation project in the Cattaraugus Creek - Zoar Watershed in New York.

7.5 Ongoing and Upcoming Activities

The Public Involvement Subcommittee is at present working on improvement of the Binational LaMP website. Placed online in 1998, the site currently has basic information about the LaMP and its organizational structure, as well as publications or products of the LaMP. We are seeking to make it a place where the public can go to answer their questions and learn about the Lake Erie LaMP.

7.6 How to Get Involved

If you would like to receive information as it becomes available, go to the binational websites:

www.on.ec.gc.ca/water/greatlakes/lakes/erie; www.epa.gov/glnpo/lakeerie/; or www.binational.net. Or join the Lake Erie Network by contacting, Marlene O'Brien, Environment Canada, or Daniel O'Riordan, U.S. EPA.

Marlene O'Brien
Environment Canada
867 Lakeshore Road,
Burlington, Ontario L7R 4A6
Fax: 905-336-4906
marlene.obrien@ec.gc.ca

Daniel O'Riordan
United States Environmental Protection Agency
77 West Jackson Boulevard T-13J,
Chicago, Illinois 60604
Fax: 312-886-9697
oriordan.daniel@epa.gov

If you would like to become a member of the Forum, please contact Teresa Hollingsworth in Canada, or Peter Wise in the United States.

Teresa Hollingsworth
FOCALerie
1424 Clarke Road,
London, Ontario N5V 5B9
Fax: 519- 451-1188
hollingswortht@thamesriver.on.ca

Peter Wise
The Delta Institute
53 West Jackson Boulevard, Suite 230,
Chicago, Illinois 60604
Fax: 312-554-0193
pwise@delta-institute.org

Section 8: Human Health

8.1 Introduction

There is concern about the effects that Great Lakes' contaminants and, in particular persistent, bioaccumulative toxic chemicals, may have on human health. The 1987 Protocol to the Great Lakes Water Quality Agreement of 1978 (GLWQA) states that Lakewide Management Plans (LaMPs) for open lake waters shall include: "A definition of the threat to human health or aquatic life posed by Critical Pollutants, singly or in synergistic or additive combination with another substance, including their contribution to the impairment of beneficial uses." Critical pollutants are those persistent bioaccumulative toxic chemicals that have caused, or are likely to cause, impairments of the beneficial uses of each Great Lake. Three of these beneficial uses (fish consumption, drinking water consumption and recreational water use) are directly related to human health. The goal of this Lake Erie LaMP section is to fulfill the human health requirements of the GLWQA, including:

- Define the threat to human health and describe the potential adverse human health effects arising from exposure to critical pollutants and other contaminants (including microbial contaminants) found in the Lake Erie basin;
- Address current and emerging human health issues of relevance to the LaMP but not currently addressed in the other components of the LaMP; and
- Identify implementation strategies currently being undertaken to protect human health and suggest additional implementation strategies that would enhance the protection of human health.

In defining the threat to human health from exposure to the Lake Erie LaMP critical pollutants (PCBs and mercury), and the other Lake Erie LaMP pollutants of concern (Table 5.2), this assessment applies a weight of evidence approach that uses the overall evidence from wildlife studies, experimental animal studies, and human studies in combination. In addition to examining the chemical pollutants of concern to human health for Lake Erie, this section also examines microbial pollutants in recreational and drinking water.

The World Health Organization defines human health as a "state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (World Health Organization 1984). Therefore, when assessing human health, all aspects of well-being need to be considered, including physical, social, emotional, spiritual and environmental impacts on health. Human health is influenced by a range of factors, such as the physical environment (including environmental contaminants), heredity, lifestyle (smoking, drinking, diet and exercise), occupation, the social and economic environment the person lives in, or combinations of these factors. Exposure to environmental contaminants is one among many factors that contribute to the state of our health (Health Canada 1997).

Consideration of human health in the Lake Erie basin must also take into account the diversity of the Lake Erie basin population, which includes a range of ethnic and socioeconomic groups. Certain subpopulations, such as high fish consumers, may have higher exposures to persistent toxic chemicals than the general population. In addition, some subpopulations, such as the elderly, immunologically compromised, women of child-bearing age, the fetus, nursing infants, and children may be more susceptible to the effects of persistent bioaccumulative toxic chemicals (Johnson et al. 1998; Health Canada 1998d). Therefore, the discussion of health issues in this section looks at the health of the general population as well as subpopulations at increased risk of exposure and health effects.

8.2 Great Lakes Human Health Network

In an effort to improve Great Lakes-related human health communication across the basin and to address health issues common to all the Great Lakes, the Great Lakes Human Health Network (Network) was established. The Network was formed in December 2002 under the guidance of the Binational Executive Committee (BEC) to create a forum to identify and discuss human health issues directly related to Great Lakes water quality.

The Network is a voluntary partnership of representatives from both U.S. and Canadian government agencies, and also includes the involvement of public health experts. The Network was specifically designed to support the LaMP and Remedial Action Plan (RAP) processes and to facilitate addressing human health issues that may go beyond the more typical issues of fish and wildlife consumption advisories, beach postings and clean drinking water.

Currently, the Network has representatives from six federal government agencies, five tribal government agencies, eleven state and provincial government agencies, and one county government agency. Network membership continues to build. To learn more about the Network, go to www.epa.gov/glnpo/health.html.

8.3 Pathways of Exposure and Human Health

The three major routes through which chemical and microbial pollutants enter the human body are by ingestion (water, food, soil), inhalation (airborne), and dermal contact (skin exposure). The major pathway is by ingestion, particularly of food. For the LaMP these largely relate to the following beneficial use impairments: fish and wildlife consumption advisories, restrictions on drinking water, and beach postings. Awareness of the underlying causes of these restrictions (e.g., chemical and microbial contaminants) and the associated health consequences will allow public health agencies to develop societal responses protective of public health. Desired outcomes for human health and the exposure pathways they relate to are identified in Table 8.1.

The scope of the Lake Erie LaMP includes pathways of exposure through the water. Therefore, air pollution is not discussed. Nonetheless, air pollution as it relates to the air we breathe is a key health issue for the Lake Erie basin, and programs and initiatives are in place in both the U.S. and Canada that address this issue. For the United States, the Clean Air Act, implemented by the U.S. EPA and state agencies, is primarily responsible for ensuring the quality of ambient air by regulating point and mobile source emissions to the environment (for more information refer to www.epa.gov/oar/oarhome.html). The Occupational Safety and Health Administration implements the Occupational Safety and Health Act that protects health in the workplace - including health related to air quality (for more information refer to www.osha.gov).

In Canada, Health Canada conducts air pollution health effects research, risk assessments and exposure guidelines creation through the Air Pollution Health Effects Research Program in its Environmental Health Directorate (www.hc-sc.gc.ca/hecs-sesc/hecs/index.htm). The Province of Ontario also has programs targeted at the protection of humans from exposure to air pollution.

The critical pollutants and chemical pollutants of concern in Lake Erie include organochlorines and metals that are known to cause adverse health effects in animals and humans. These chemicals do not break down easily, persist in the environment and bioaccumulate in aquatic biota, animal and human tissue - thus they are called *persistent bioaccumulative toxic* chemicals (PBTs). Organochlorines tend to accumulate in fat (such as adipose tissue and breast milk), and metals tend to accumulate in organs, muscle and flesh. Food is the primary route of human exposure to these PBT chemicals, and consumption

Table 8.1: Human Health-Related Desired Outcomes, and Pathways of Exposure

Desired Outcomes	Pathway of Exposure
Fishable - We can all eat any fish	Ingestion of food (fish)
Drinkable - Treated drinking water is safe for human consumption; We can all drink the water	Ingestion of water
Swimmable - All beaches are open and available for public swimming; We can all swim in the water with no health impacts	Incidental ingestion of water, dermal contact, inhalation of water spray from splashing, etc.

of Great Lakes fish is the most important source of exposure originating directly from the lakes. Sources from air, soil/dust, and water constitute a minor route of exposure (Health Canada 1998e; Johnson et al. 1998).

Since the 1970s, there have been steady declines in many PBT chemicals in the Great Lakes basin. For example, lead concentrations in blood and organochlorine contaminants in breast milk have declined. However, PBT chemicals, because of their ability to bioaccumulate and persist in the environment, continue to be a significant concern in the Lake Erie basin. Therefore, public health advisories and other guidelines should be followed to minimize contaminant exposures. Most of the health effects studies for Great Lakes PBT chemicals have focused on fish consumption.

Photo: Upper Thames River Conservation Authority

8.3.1 Drinking Water

Access to clean drinking water is essential to good health. The waters of Lake Erie and surrounding areas are a primary source of drinking water for people who live in the Lake Erie basin. The average adult drinks about 1.5 liters of water a day, so health effects could be serious if high levels of some contaminants are present (Health Canada 1993, 1997).

A variety of contaminants can adversely affect drinking water, including: microorganisms (e.g. bacteria, viruses and protozoa, such as *cryptosporidium*); chemical contaminants (both naturally occurring, synthetic and anthropogenic); and radiological contaminants, including naturally occurring inorganic and radioactive materials (IJC 1996; Health Canada 1997; Lake Erie LaMP 1999; OME 1999). Some contaminants in raw water supplies, such as aluminum, arsenic, copper and lead, can be both naturally occurring and result from human activities. Other contaminants, such as household chemicals, industrial products, fertilizers (including nitrates), human and animal wastes, and pesticides may also end up in raw water supplies (U.S. EPA 1999a; Health Canada 1998b).

Microbial contamination of drinking water can pose a potential public health risk in terms of acute outbreaks of disease. Some individuals or groups, particularly children and the elderly, may be more sensitive to contaminants in drinking water than the average person (Health Canada 1993). The illnesses associated with contaminated drinking water are mainly of a gastrointestinal nature, including diarrhea, nausea, stomach cramps, and other symptoms, although some pathogens are capable of causing severe and life-threatening illness (Health Canada 1995a). Microbial contamination of municipal water supplies has been largely eliminated through treatment of drinking water prior to distribution to the consumer (contaminants are removed and disinfectants such as chlorine are added to prevent waterborne disease). As a result of this treatment, diseases such as typhoid and cholera have been virtually eliminated. Although other disinfectants are available, chlorine still tends to be the treatment of choice. When used with multiple barrier systems (i.e. coagulation, flocculation, sedimentation, filtration), chlorine is effective against virtually all infective agents (U.S. EPA and Government of Canada 1995; Health Canada 1993, 1997 and 1998b).

Drinking water utilities today find themselves facing new responsibilities. While their mission has always been to deliver a dependable and safe supply of water to their customers, the challenges inherent in achieving that mission have expanded to include security and counter-terrorism. In the Public Health Security and Bioterrorism and Response Act of 2002, the U.S. Congress recognized the need for drinking water systems to undertake a more comprehensive view of water safety and security. The Act amends the U.S. Safe Drinking Water Act and specifies actions community water systems and the U.S. EPA must take to improve the security of the nation's drinking water infrastructure. For more information, go to www.epa.gov/safewater/security/index.html.

In 2002 the Province of Ontario passed the Safe Drinking Water Act. This Act expands on existing policy and practice and introduces new features to protect drinking water in Ontario. Its purpose is to protect human health through the control and regulation of drinking water systems and drinking water testing. For more information refer to www.ene.gov.on.ca/envision/water/sdwa/.

8.3.2 Recreational Water

The Great Lakes are an important resource for recreational activities that involve full body contact with water, such as swimming, water-skiing, sailboarding and wading. Apart from the risks of accidental injuries, the major human health concern for recreational waters is microbial contamination by bacteria, viruses, and protozoa (Health Canada 1998; World Health Organization 1998).

Many sources or conditions can contribute to microbiological contamination, including combined sewer overflows after heavy rains (Whitman et al. 1995). On-shore winds can stir up sediment or transport bacteria in from contaminated areas. Animal/pet waste may be deposited on beaches or washed into storm sewers. Agricultural runoff, such as manure, is another source. Storm water runoff in rural and wilderness area watersheds can increase densities of fecal streptococci and fecal coliforms as well (Whitman et al. 1995). Other contaminant sources include infected bathers/swimmers; direct discharges of sewage from recreational vessels; and malfunctioning private systems (e.g. cottages, resorts) (Health Canada 1998; Whitman et al. 1995; World Health Organization 1998).

The Great Lakes Water Quality Agreement calls for recreational waters to be substantially free from bacteria, fungi, and viruses. Human exposure to microorganisms occurs primarily through ingestion of water, and can also occur via the entry of water through the ears, eyes, nose, broken skin, and through contact with the skin. Gastrointestinal disorders, respiratory illness and minor skin, eye, ear, nose, and throat infections have been associated with microbial contamination of recreational waters (Health Canada 1998a; Whitman et al. 1995; World Health Organization 1998). The risk of illness is dependent upon the degree of water pollution, the individual's level of exposure, immunization status (e.g., polio), and the general health of the individual. For this reason, the protection of public health is directed at controlling microbial pollutants in recreational waters. See Table 8.2 for the swimming associated illnesses.

Table 8.2: Pathogens and Swimming-Associated Illnesses

Pathogenic Agent	Disease
Bacteria	
Campylobacter jejuni	Gastroenteritis
E. coli	Gastroenteritis
Salmonella typhi	Typhoid fever
Other salmonella species	Various enteric fevers (often called paratyphoid), gastroenteritis, septicemia (generalized infections in which organisms multiply in the bloodstream)
Shigella dysenteriae and other species	Bacterial dysentery
Vibrio cholera	Cholera
Yersinia spp.	Acute gastroenteritis (including diarrhea, abdominal pain)
Viruses	
Adenovirus	Respiratory and gastrointestinal infections
Coxsackievirus (some strains)	Various, including severe respiratory diseases, fevers, rashes, paralysis, aseptic meningitis, myocarditis
Echovirus	Various, similar to coxsackievirus (evidence is not definitive except in experimental animals)
Hepatitis	Infectious hepatitis (liver malfunction); also may affect kidneys and spleen
Norwalk virus	Gastroenteritis
Poliovirus	Poliomyelitis
Reovirus	Respiratory infections, gastroenteritis
Rotavirus	Gastroenteritis
Protozoa	
Balantidium coli	Dysentery, intestinal ulcers
Cryptosporidium	Gastroenteritis
Entamoeba histolytica	Amoebic dysentery, infections of other organs
Giardia lambia	Diarrhea (intestinal parasite)
Isospora belli and *Isospora hominus*	Intestinal parasites, gastrointestinal infection
Toxoplasma gondii	Toxoplasmosis

(NRDC, 2003)

Studies have shown that swimmers and people engaging in other recreational water sports have a higher incidence of symptomatic illnesses such as gastroenteritis, otitis, skin infection, conjunctivitis, and acute febrile respiratory illness following activities in polluted recreational waters (Dewailly 1986; World Health Organization 1998). Although current studies are not sufficiently validated to allow calculation of risk levels (Health Canada 1992), there is some evidence that swimmers/bathers tend to be at a significantly elevated risk of contracting certain illnesses (most frequently upper respiratory or gastrointestinal illness) when compared with people who do not enter polluted water (Dufour 1984; Seyfried 1985a, b; U.S. EPA 1986; World Health Organization 1998). In addition, children, the elderly, and people with weakened immune systems are more likely to develop illnesses or infections after swimming in polluted water (Health Canada 1998). Despite these studies, there are challenges in establishing a clear relationship between recreational water exposure and disease outcomes. Less severe symptoms resulting from exposure to microorganisms are not usually reported, which makes statistics on cases related to recreational water exposure difficult to determine. In addition, the implicated body of water is not often tested for the responsible organism and when it is tested, the organism is not usually recovered from the sample. With the exception of gastrointestinal illness, a direct relationship between bacteriological quality of the water and symptoms has not been shown — a causal relationship exists between gastrointestinal symptoms and recreational water quality as measured by indicator-bacteria concentrations (World Health Organization 1998). Therefore, research efforts are focused on epidemiological studies to establish the relationships between diseases and the presence of microorganisms in the water (Health Canada 1997; Health Canada 1998; U.S. EPA 1999).

The primary cause for beach closings and advisories is the high level of indicator bacteria in recreational waters. Elevated bacterial levels can be the result of several different problems ranging from flooding to point source releases. The best way to protect swimmers is to eliminate the need for beach closings in the first place. Conserving water, keeping septic systems maintained, and properly disposing of boat sewage and animal waste helps to reduce beach water contamination. Sewage treatment plants need to be improved and direct discharges of raw sewage into the water from combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) need to be eliminated.

Photo: Upper Thames River Conservation Authority

Chemical contaminants such as PAHs and PCBs have been identified as a possible concern for dermal (skin) exposure in recreational waters. Dermal exposure may occur when people come into contact with contaminated sediment or contaminated suspended sediment particulates in the water. PAHs and PCBs adsorbed to these particulates would adhere to the skin. There is little information available regarding chemical contaminants with the potential to cause effects such as skin rashes, or how much of a chemical might be absorbed through the skin, with the potential to cause systemic effects, such as cancer (Hussain et al. 1998; Lake Erie LaMP 1999).

8.3.3 Fish Contaminants

Exposure assessments from all sources (air, water, food and soil) were completed for the Canadian Great Lakes basin general population for 11 PBT chemicals, including PCBs and mercury. The total estimated daily intake averaged over a lifetime was well below the Tolerable Daily Intake (TDI) established by Health Canada (Health Canada, 1998c). Consequently, the approach by various agencies has been to examine groups at higher risk of exposure to PBT chemicals from Great Lakes sources, such as high consumers of sport fish.

Fish are low in fat, high in protein, and may have substantial health benefits when eaten in place of high-fat foods. The levels of the chemicals in fish from the Lake Erie basin are generally low and do not cause acute illness. However, chemicals such as mercury and PCBs enter the aquatic environment and build up in the food chain. Continued low-level exposure to these chemicals may result in adverse human health effects. People need to be aware of the presence of contaminants in sport fish and, in some cases, take action to reduce exposure to chemicals while still enjoying the benefits of catching and eating fish.

Contaminants usually persist in surface waters at very low concentrations. They can bioaccumulate in aquatic organisms and become concentrated at levels that are much higher than in the water column. This is especially true for substances that do not break down readily in the environment, such as the Lake Erie LaMP critical pollutants PCBs and mercury. As contaminants bioaccumulate in aquatic organisms, this effect biomagnifies with each level of the food chain. As a result of this effect, the concentration of contaminants in the tissues of top predators, such as lake trout and large salmon, can be millions of times higher than the concentration in the water. Figure 8.1 illustrates an example of the changes in PCB concentration (in parts per million, ppm) at each level of a Great Lakes aquatic food chain. The highest levels are reached in the eggs of fish-eating birds such as herring gulls.

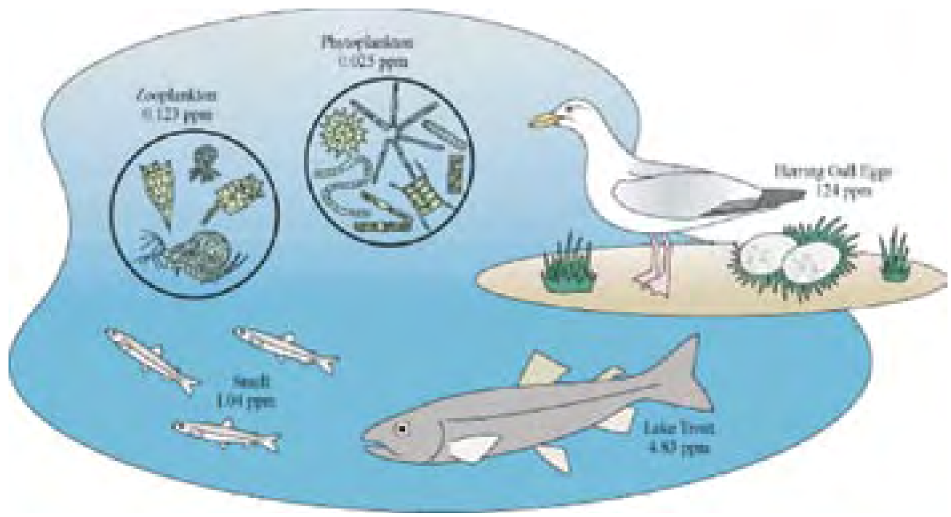


Figure 8.1: Persistent organic chemicals such as PCBs bioaccumulate and biomagnify

8.4 Evidence for Potential Health Effects - Weight of Evidence Approach to Linking Environmental Exposure

The following three subsections describe selected studies that have reported associations between PBT chemical exposures and effects in wildlife, laboratory animals and human populations. Because of the ethical issue of exposing humans to toxic substances and factors such as a small sample size and presence of multiple chemicals, human studies are often limited in their ability to establish a causal relationship between exposure to chemicals and potential adverse human health effects. Human studies looking at causal relationships between human exposure to environmental contaminants and adverse health outcomes are limited and the results uncertain. Therefore, a weight of evidence approach is used, where the overall evidence from wildlife studies, experimental animal studies, and human studies is considered in combination. It utilizes the available information from wildlife and controlled animal experiments to supplement the results of human studies toward assessing the risks to human health from exposure to PBT chemicals. The use of wildlife data assumes that animals can act as sentinels for adverse effects observed in humans (Johnson and Jones 1992).

8.4.1 Wildlife Populations

Research over the past 25 years has shown that a variety of persistent, bioaccumulative contaminants in the Great Lakes food chain are toxic to wildlife (Health Canada 1997). Reproductive impairments have been described in avian, fish, and mammalian populations in the Great Lakes. For example, egg loss due to eggshell thinning has been observed in predatory birds, such as the bald eagle, within the Great Lakes (Menzer and Nelson 1980). After feeding on Great Lakes fish for two or more years, immigrant birds (eagles) were shown to have a decline in reproductive success (Colburn et al. 1993). Developmental effects in the form of congenital deformities (e.g. crossed mandibles, club feet) have also been reported in the avian population within the Great Lakes basin (Stone 1992).

Effects on the endocrine system and tumor formations have been detected in fish populations. Researchers have reported enlarged thyroids in all of the 2 to 4 year-old Great Lakes salmon stocks that were examined (Leatherland 1992). Tumors associated with exposure to high levels of PAHs have been detected in brown bullhead in the Great Lakes area (Baumann et al. 1982).

Effects on the immune system have also been documented. At a number of Great Lakes sites, a survey of herring gulls and Caspian terns demonstrated a suppression of T-cell-mediated immunity following prenatal exposure to organochlorine pollutants, particularly

PCBs (Grasman et al. 1996). Section 4 provides a more detailed description of the effects of chemicals on wildlife.

Photo: U.S. EPA Great Lakes National Program Office

8.4.2 Animal Experiments

A number of animal experiments have demonstrated a wide range of health outcomes from exposure to PCBs, mercury and chlorinated dibenzo-p-dioxins (CDD).

PCBs (polychlorinated biphenyls): Animals exposed orally to PCBs developed effects to the hepatic, immunological, neurological, developmental and reproductive systems. Effects have also been reported in the gastrointestinal and hematological systems (ATSDR 1998). Animal ingestion studies strongly support the finding that more highly chlorinated PCBs (i.e., 60% chlorine by weight) are carcinogenic to the livers of rats, while the lower chlorinated PCBs result in a lower incidence of total tumors and more benign tumors (Buchmann et al. 1991; Sargent et al. 1992.)

Mercury: Long-term, high level animal ingestion exposure to mercury has been associated with cardiovascular (Arito and Takahashi 1991), developmental (Fuyuta et al. 1978; Nolen et al. 1972; Inouye et al. 1985), gastrointestinal (Mitsumori et al. 1990), immune (Ilback 1991), renal (Yasutake et al. 1991; Magos et al. 1985; Magos and Butler, 1972; Fowler 1972) and reproductive effects (Burbacher et al. 1988; Mitsumori et al. 1990; Mohamed et al. 1987). The studies also indicate that the nervous system is particularly sensitive to mercury exposure by ingestion (Fuyuta et al. 1978; Magos et al. 1980, 1985). In addition, growth of kidney tumors has been reported in animals administered methylmercury in drinking water or diet for extended periods (Mitsumori et al. 1981, 1990).

CDDs (chlorinated dibenzo-p-dioxins): In specific species (e.g., guinea pig), very low levels of 2,3,7,8-TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) have resulted in the death of the exposed animal after a single ingestion dose (NTP 1982). At non-lethal levels of 2,3,7,8-TCDD by ingestion, other effects reported in animals include weight loss (NTP 1982), biochemical and degenerative changes in the liver (NTP 1982; Kociba et al. 1978), and a decline in blood cells (Kociba et al. 1978). Dermal effects in animals (e.g., hair loss, chlor-acne) have also been reported by ingestion exposure (McConnell et al. 1978). In many species, the immune system and fetal development are particularly susceptible to 2,3,7,8-TCDD exposure. Offspring of animals receiving oral exposure to 2,3,7,8-TCDD developed birth defects such as skeletal deformities and kidney defects, weakened immune responses, impaired reproductive system development, and learning and behavior impairments (Giavini et al. 1983; Gray and Ostby 1995; Tryphonas 1995; Schantz and Bowman 1989; Schantz et al. 1992). Reproductive effects in the form of miscarriages were reported in rats, rabbits, and monkeys exposed orally to 2,3,7,8-TCDD during pregnancy (McNulty 1984). Rats of both sexes were observed to have endocrine changes in the form of alterations in sex hormone levels with dietary exposure. Other reproductive effects include a decline in sperm production in male rats. Cancer of the liver, thyroid, and other organs in rats and mice exposed orally to 2,3,7,8-TCDD were measured (NTP 1982; Kociba et al. 1978). Research evidence is also increasing supporting the neurotoxic effect for mammals and birds from ingestion exposure to dioxin-like compounds, including certain PCBs and CDFs. Changes in thyroid hormones and neurotransmitters, singly or together, at critical periods in the development of the fetus are considered responsible for the neurological changes (Brouwer et al. 1995; De Vito et al. 1995; Henshel et al. 1995b; Henshel and Martin 1995a; Vo et al. 1993).

8.4.3 Human Health Studies

Demonstrating health effects in humans from chronic, low-level exposure to persistent organic pollutants typically encountered in the Great Lakes region is a challenge for researchers. Exposure to contaminants from Great Lakes fish is dependent upon the amount eaten and species consumed. Overall, there is limited information available on exposure levels, body burdens and health effects for people who consume Lake Erie fish. Currently, the Agency for Toxic Substances and Disease Registry (ATSDR) is funding studies investigating populations that reside in the Lake Erie basin and consume Lake Erie fish. The ATSDR studies will determine exposure and body burden levels, and potential health effects. In addition, two Health Canada fish consumption studies include participants from the Lake Erie basin. Along with results from the Lake Erie studies, research examining other Great Lakes will be used to assess risks and benefits of eating Great Lakes fish.

Exposure Studies

Due to the effects of bioaccumulation and biomagnification, fish consumption has been shown to be a major pathway of human exposure to PBT chemicals such as PCBs (Birmingham et al. 1989; Fitzgerald et al. 1996; Humphrey 1983; Newhook 1988), exceeding exposures from land, air, or water sources (Humphrey 1988). Humphrey (1988) reported that PCBs were the dominant contaminants detected in Lake Michigan trout (3,012 parts per billion or ppb) and chinook and coho salmon (2,285 ppb), surpassing other contaminants such as DDT (1,505 ppb, 1,208 ppb), hexachlorobenzene (5 ppb, 5 ppb), oxychlordane (25 ppb, none shown), trans-nonachlor (195 ppb, 162 ppb), and dieldrin (75 ppb, 53 ppb), respectively in trout and salmon. Fish specimens collected from the dinner plate of study participants were used to determine these median PCB concentrations. Recently, total PCB levels have decreased in most Lake Michigan fish species and appear to remain below the FDA action level of 2000 ppb, but the concentrations in chinook and coho salmon have risen slightly since the late 1980s (Stow et al. 1995).

Early investigations of Lake Michigan fish consumption have broadened our knowledge about transmission of contaminants from fish to humans, including maternal exposure of the fetus and infant. Investigating a cohort of State of Michigan fish eaters, Humphrey (1988) discovered that sport anglers who regularly consumed Great Lakes salmon and trout (consumption rate of 24 pounds/year or 11 kg/year) had median serum PCB levels approximately four times higher (56 ppb) than those who consumed no Great Lakes fish (15 ppb). PCBs have also been detected in adipose tissue (Stellman et al. 1998), breast milk (Jacobson et al. 1984), and cord blood (Fein et al. 1984) and associated with consumption of contaminated fish (ATSDR 1998). Schwartz et al. (1983) demonstrated that consumption of Lake Michigan fish was positively associated with the PCB concentration in maternal serum and breast milk. Maternal serum PCB concentrations were also positively associated with the PCB levels in the umbilical cord serum of the infant (Jacobson et al. 1983).

Although the levels of PCBs have declined in most species of Lake Michigan fish, lipophilic pollutants, such as PCBs, have a tendency to bioaccumulate in the human body. Hovinga et al. (1992) reported a mean serum PCB concentration of 20.5 ppb in 1982 for persons consuming >24 pounds of Lake Michigan sport fish per year, and 19 ppb in 1989, demonstrating little decline within the 7 year interval. For those ingesting <6 pounds of Lake Michigan sport fish per year, the mean serum PCB concentrations were 6.6 ppb in 1982, and 6.8 ppb in 1989. The mean serum PCB concentrations for those consuming <6 pounds of Lake Michigan fish per year are comparable to the mean serum PCB levels of 4 to 8 ppb found in the general population who do not have occupational PCB exposure (Kreiss 1985).

Research has shown that at risk communities for exposure to contaminants from fish consumption include Native Americans, minorities, sport anglers, the elderly, pregnant women, and fetuses and infants of mothers consuming contaminated Great Lakes fish (Dellinger et al. 1996, Fitzgerald et al. 1996, Lonky et al. 1996, Schantz et al. 1996). These communities may consume more fish than the general populations or have physiologic attributes, such as physical and genetic susceptibilities, that may cause them to be a greater risk. Higher body burdens of mean serum PCBs and DDE were found in an older cohort of Lake Michigan fish eaters (i.e., 50 years of age) who were compared to non-fish eaters

(Schantz et al. 1996). Fish eaters had mean serum PCB levels of 16 ppb while the non-fish eaters had mean levels of 6 ppb. For DDE, fish eaters had mean serum levels of 16 ppb and the non-fish eaters had a mean level of 7 ppb.

Gender difference in fish consumption is an issue of interest that is being investigated, toward better identifying at-risk populations. One Michigan sport anglers study, with subjects between the ages of 18-34 years, demonstrated gender differences with males tending to consume more fish than female subjects (Courval et al. 1996). Conversely, Health Canada's Great Lakes Fish Eaters Study (discussed below) found that women in the high fish consumption group eat more fish than men (Kearney 2000, personal communication).

In a recent Health Canada study carried out in five areas of concern in the lower Canadian Great Lakes, 4,637 shoreline fishers were interviewed. The demographic data show that there is no such thing as a *typical* fisher. People who like to fish come from different cultural backgrounds, are different ages and have different occupations. Thirty-eight percent of the shoreline fishers interviewed reported eating at least one meal of fish during the previous 12 months. Twenty-seven percent of shoreline fishers interviewed reported eating more than 26 meals of fish in a year. As the number of fish meals consumed increased, so did the likelihood that parts of the fish other than the fillet were being consumed. Approximately one third of the fish eaters said that they used the *Guide to Eating Ontario Sport Fish* (Health Canada, 2000).

A concurrent project, the Great Lakes Fish Eaters Study (not yet released) took a more in-depth look at exposure to environmental contaminants in people eating large amounts of Great Lakes fish. Environmental contaminant levels were measured in blood samples collected from the study participants. As well, nutritional and social benefits associated with consumption of Great Lakes fish were examined (Kearney, 2000, personal communication).

In a study by Kearney et al. done in 1992-93, blood levels of PCBs in men and women between Great Lakes fish eaters and non-fish eaters were compared for Mississauga and Cornwall (in the Lake Ontario basin). For male fish eaters the median level was 5.5 ppb, for male non-fish eaters it was 3.9 ppb. For women fish eaters and non-fish eaters the median levels were 3.4 and 3.2 ppb, respectively. These differences were statistically significant for men only. Relative to fish eaters and families on the north shore of the St. Lawrence River (geometric mean 35.2 ppb) and Quebec Inuit (geometric mean 16.1 ppb), these values are low. Total mercury levels measured in the same participants were also low; the median levels for male Great Lakes fish eaters and non-eaters were 2.65 and 1.70 ppb, respectively. Median levels for female Great Lakes fish eaters and non-eaters were 2.10 and 1.45 ppb, respectively. Levels were generally at the lower end of the *normal acceptable range* (< 20 ppb) as defined by the Medical Services Branch of Health Canada and based on WHO guidelines.

Hanrahan et al. (1999) corroborated previous findings relating frequent Great Lakes sport fish consumption to a higher body burden for PCBs and DDE. The study examined relationships between demographic characteristics, Great Lakes sport fish consumption, PCB, and DDE body burdens. The blood serum PCB and DDE levels in a large cohort (538) of sport fish consumers for Lakes Michigan, Huron and Erie were significantly higher than in reference groups. Body burdens varied by exposure group, gender, and Great Lake. Years of consuming Great Lakes fish were the most important predictor of PCB levels, while age was the best predictor of DDE levels.

Falk et al. (1999) examined fish consumption habits and demographics in relation to serum levels of dioxin, furan, and coplanar PCB congeners in one hundred subjects. Body burdens varied by gender and lake (Michigan, Huron, and Erie). Between-lake differences were consistent with fish monitoring data. Consumption of lake trout and salmon was a significant predictor of coplanar PCBs. Consumption of lake trout was also a significant predictor of total furan levels. Fish consumption was not significantly correlated with total dioxin levels.

Health Effects

A health effect associated with a particular exposure to a chemical contaminant does not in itself establish causality. The association becomes of interest when a number of different researchers produce similar findings. A small number of study participants, presence of multiple chemical exposures, and exposure data that lack a certain degree of precision often limit occupational and environmental epidemiologic studies examining human health effects from chemical contaminants. When epidemiological studies are judged against factors, among which are consistency of findings, dose-response effect, biological plausibility, and strength of association (i.e. greater risk in the exposed vs. non-exposed), the association between observed exposure and a subsequent adverse health effect, though not establishing causality, is made stronger.

Developmental, reproductive, neurobehavioral or neurodevelopmental, and immunological effects of exposure to lipophilic pollutants (i.e. organochlorines) have been examined in studies conducted within the Great Lakes basin and outside the basin. The following are selected studies that have reported an association between exposure through sport fish consumption and these outcomes.

Developmental effects in the form of a decrease in gestational age and low birth weight have been observed in a Lake Michigan Maternal Infant Cohort exposed prenatally to PCBs (Fein et al. 1984). These findings have also been observed in offspring of women exposed to PCBs occupationally in the manufacture of capacitors in New York (Taylor et al. 1989).

Reproductive effects have also been reported. Courval et al. (1997 and 1999) examined couples and found a modest association in males between sport-caught fish consumption and the risk of conception failure after trying for at least 12 months. Exposure to PCBs in fish was also associated with a rise in the risk of infertility (Buck et al. 2000). Studies of New York state anglers have not shown a risk of spontaneous fetal death due to consumption of fish contaminated with PCBs (Mendola et al. 1995), or an effect to time-to-pregnancy among women in this cohort (Buck et al. 1997).

Neurobehavioral or neurodevelopmental effects have been reported for exposure to PBT chemicals in newborns, infants, and children of mothers consuming Great Lakes fish. Early investigations of the Lake Michigan Maternal Infant Cohort revealed newborn infants of mothers consuming >6.5 kg/year of Lake Michigan fish had neurobehavioral deficits of depressed reflexes and responsiveness, when compared to non-exposed controls (Jacobson et al. 1984). The fish-eating mothers consumed an average of 6.7 kg of Lake Michigan contaminated fish per year equal to 0.6 kg or 2 to 3 salmon or lake trout meals/month. Prior to study admission, exposed mothers were required to have fish consumption that totaled more than 11.8 kg over a 6-year period. Subsequent studies of the Michigan Cohort have revealed neurodevelopmental deficits in short-term memory at 7 months (Jacobson et al. 1985) and at 4 years of age (Jacobson et al. 1990b), and also growth deficits at 4 years associated with prenatal exposure to PCBs (Jacobson et al. 1990a). A more recent investigation of Jacobson's Michigan Cohort revealed that children most highly exposed prenatally to PCBs showed IQ

deficits in later childhood (11 years of age) (Jacobson and Jacobson 1996). Highly exposed children received prenatal and postnatal PCB exposure equal to at least 1.25 ppm in maternal milk, 4.7 ppb in cord serum, or 9.7 ppb in maternal serum. The authors attributed these intellectual impairments to in-utero exposure to PCBs.

The Oswego Newborn and Infant Development Project examined the behavioral effects in newborns of mothers who consumed Lake Ontario fish that were contaminated with a variety of PBT chemicals. These infants were examined shortly after birth (12-24 and 25-48 hours). Lonky et al. (1996) found that women who had consumed >40 PCB equivalent pounds of fish in their lifetime had infants who scored more poorly in a behavioral test (Neonatal Behavioral Assessment Scale) than those in the low-exposure (<40 PCB equivalent pounds of fish) or control group. In a follow-up study Stewart et al. (1999), concluded that the most heavily chlorinated and persistent PCB homologues were elevated in the umbilical cord blood of infants whose mothers ate Great Lakes' fish. The concentration was significantly dependent on how recently the fish were consumed relative to pregnancy. A further study attempting to relate the level of PCBs to scores in infants is underway.

Mergler and coworkers (1997) reported early nervous dysfunction in adults who consumed St. Lawrence River fish. However, in initial testing, neurotoxic effects were not observed by Schantz and coworkers (1999) in an older adult population (i.e. >50 years) of Lake Michigan fish-eaters with exposure to PCB and DDE. This study is ongoing. Immunological effects have also been reported. Smith's study (1984) demonstrated that maternal serum PCB levels during pregnancy were positively associated with the type of infectious diseases that infants developed during the four months after birth. In addition, incidence of infections has been shown to be associated with the highest fish consumption rate for mothers - i.e., at least three times per month for three years (Swain 1991; Tryphonas 1995).

Other health effects have been documented with PCB exposure. Elevated serum PCB levels were associated with self-reported diabetes and liver disease in cohorts of Red Cliff and Ojibwa Native Americans (Dellinger et al. 1997, Tarvis et al. 1997). Fischbein and coworkers (1979) found that workers exposed to a variety of PCB aroclors reported joint pain.

The nervous system is particularly sensitive to the effects of methylmercury exposure including tingling sensation in the extremities, unsteady gait, memory loss, paraplegia, hallucination, loss of consciousness and death (Tsubaki and Takashi 1986; Al-Mufti et al. 1976). Developmental effects have also been observed in infants born to mothers exposed to methylmercury, including brain damage, mental retardation and retention of primitive reflexes (Cox et al, 1989).

A summary of health effects studies inside and outside the Great Lakes basin can be found in the paper published by Johnson and coworkers (1998). The U.S. Agency for Toxic Substances and Diseases Registry (ATSDR) has published toxicological profiles for hazardous substances, including PCBs and mercury. The full reports can be obtained from ATSDR, and information is available at www.atsdr.cdc.gov/toxpro2.html. Health Canada has also published documents about fish consumption and health effects (www.hc-sc.gc.ca/english/protection/warnings.html.)

8.5 Exposure and Health Effects Research Needs for PBT Chemicals

Since the 1970s, there have been steady declines in many PBT chemicals in the Great Lakes basin, leading to declines in levels in the environment and in animal and human tissues. Within the ecosystem, there are encouraging signs and successes. For example, contaminant declines have been observed at most Great Lakes sites sampled for contaminants in herring gull eggs (Environment Canada and U.S. EPA 1999).

Reductions of PBT chemicals in human tissues include lead in blood, and organochlorine contaminants in breast milk. This translates into a reduced risk to health for these contaminants. However, PBT chemicals, because of their ability to bioaccumulate and persist in the environment, continue to be a significant concern in the Lake Erie basin. Human health research has identified fish consumption as the major pathway of exposure to contaminants from Lake Erie and other Great Lakes. Body burdens from consumption of contaminated fish have been noted in highly exposed populations and human health effects have subsequently been reported. Despite these findings, issues related to environmental exposures and human health still remain. This supports the need for continued reductions of PBT chemicals in the Lake Erie basin. Health research needs to continue, but a shift in priorities is now needed to prevention and intervention strategies. Efforts on public health advisories to protect health from current environmental exposures, and public outreach related to risks and benefits of fish consumption, need to continue where appropriate.

Photo: Upper Thames River Conservation Authority

Additional research is needed in the following areas:

1. Continue to assess the role of PBT chemicals on neurobehavioural and neurodevelopmental effects.
2. Improve the assessments of chemical mixtures.
3. Assess the role that endocrine disruption may play in human health effects, such as reproductive health.
4. Research on PCB Congeners.
5. Research Biologic Markers.

8.6 Source Water Protection in Ontario *(Prepared by Karen Maaskant, Upper Thames River Conservation Authority)*

In May 2000 bacteria entered the drinking water supply of Walkerton, Ontario, resulting in the deaths of seven people and making more than 2000 sick. The resulting public inquiry, headed by the Honourable Justice Dennis R. O'Connor, investigated the circumstances that led to this tragedy and made recommendations to ensure the future safety of Ontario's drinking water. Justice O'Connor recommended that drinking water be protected by multiple barriers. These multiple barriers include:

- Protecting surface water and groundwater from becoming contaminated or overused;
- Up to date water treatment systems;
- Reliable and secure distribution systems;
- Monitoring and testing; and
- Training of water managers and staff to respond to adverse conditions.

The Clean Water Act (Canadian) was introduced in December 2005 and is currently under review. It is intended to address the recommendations contained in the Report of the Walkerton Inquiry that pertain to the protection of drinking water sources. The legislation is based on the recommendations of two expert advisory committees as well as significant consultation with stakeholders.

Justice O'Connor's report recommends that "Drinking water sources should be protected by developing watershed-based source protection plans. Source protection plans should be required for all watersheds in Ontario" (O'Connor 2002). The report also recommends that "The Ministry of the Environment should ensure that draft source protection plans are prepared through an inclusive process of local consultation. Where appropriate, this process should be managed by conservation authorities" (O'Connor 2002).

As Conservation Authorities (CAs) are organized on a watershed basis, they were recognized by many to be logical organizations to facilitate the development of watershed-based source protection plans. CAs are formed as a municipal partnership pursuant to the provincial Conservation Authorities Act. The source water protection effort expands a primary focus of CAs, the development of watershed plans, to include the protection of drinking water sources.

The White Paper on Watershed-based Source Protection Planning recommended that two or more watersheds be grouped into watershed regions in order to share resources and expertise and facilitate the preparation of source protection plans (MOE 2004). Many CAs have developed partnerships and entered into agreements with the Province and Conservation Ontario to undertake background data collection. The following two partnerships have been established in the Lake Erie basin:

- The Lower Thames Valley, Upper Thames River and St. Clair Region Conservation Authorities' partnership includes almost all of the land draining into Lake St. Clair from the Canadian side, including the Thames and Sydenham Rivers, as well as smaller watersheds directly draining into the southern end of Lake Huron and the western end of Lake Erie.
- The Grand River, Long Point Region, Kettle Creek and Catfish Creek Conservation Authorities' partnership is likely to be referred to as the Lake Erie Source Protection Watershed Region as it includes most of the larger watersheds draining directly into Lake Erie.

In addition, the Essex Region CA and Niagara Region CA are preparing to undertake source water protection planning activities individually in their respective watersheds.

In each watershed region, a preliminary characterization of the watersheds and a conceptual water budget are being developed. Past watershed plans and municipal groundwater studies are key sources of information for these reports. It is expected that watershed assessment reports will also be written to assess the threats to source water. Source Protection Planning Committees will use this information to develop a source protection plan that would identify risk management activities to address the high risk threats identified in the assessment report.

8.7 Accomplishments/Activities Related to Beaches Safe to Swim *(Prepared with the assistance of Holiday Wirick, U.S. EPA)*

Many shoreline areas along Lake Erie support swimming and secondary contact recreation activities (i.e., swimming, water-skiing, and sail-boarding). Some of these areas experience elevated levels of *E. coli* bacteria. This may be due to wet weather that causes overflows from aging wastewater collection systems or treatment plants, storm water runoff from cities and farms, improperly sited or maintained septic systems, and natural sources such as waterfowl. When *E. coli* levels exceed water quality standards, "Beach Advisory" notices are posted to protect human health. Often, summers with high rainfall are reflected in more beach closings. For example, Lakeview Beach near Lorain, Ohio, was under advisement for 88 days in 2004 (a wet year) while only 14 days in 2005 (a dry year). Based on data as reported by the states, in 2005, 33 of the monitored beaches on the US Lake Erie shoreline posted at least one beach closing episode. Due to the number of potential sources, varying weather conditions, different methodologies for measuring or estimating bacteria counts, and the frequency of sampling, it is difficult to measure trends in beach closings. Changes brought under the BEACH Act (described below), should better standardize the beach monitoring program to better present trends in the future.

Photo: Jeff Brick

To improve water quality testing at the beach and to help beach managers better inform the public when there are water quality problems, Congress passed the Beaches Environmental Assessment and Coastal Health (BEACH) Act on October 10, 2000. The BEACH Act requires adoption of consistent bacterial standards at coastal waters nationwide, research on new pathogens and pathogen indicators, and publication of new or revised water quality criteria for pathogens within five years. The BEACH Act also authorizes U.S. EPA to award grants to eligible states, tribes, and territories to develop and implement beach monitoring programs at coastal and Great Lakes beaches, and to notify the public when bacteria levels are exceeded.

Progress on Developing and Implementing Beach Monitoring and Notification Plans

Since passage of the BEACH Act, approximately $7.8 million in BEACH grants have been issued to Great Lakes states to implement beach programs. This has resulted in a significant increase in the number of monitoring and notification programs at Great Lakes beaches. All of the Lake Erie states have beach monitoring and public notification programs in place at most of their coastal beaches and at all of their high priority (most frequently used) coastal beaches. Following are Lake Erie beach program summaries for Michigan, New York, Ohio, and Pennsylvania.

Michigan's Beach Program

The Michigan Department of Environmental Quality (MDEQ) has received a total of $1,084,966 in BEACH Act funding since 2002 to support monitoring programs for 431 public beaches in 41 counties along the state's 3,200 miles of Great Lakes shoreline. There are eight public beaches monitored on the Michigan side of the St. Clair River and Lake St. Clair. Along the western shore of Lake Erie there are two public sites - Luna Pier City Beach and Sterling State Park, both in Monroe County. There were no beach closures to report in 2005 for the western basin beaches; however, five beaches along Lake St. Clair reported 15 closure events totaling 180 days. An estimated $6,000 was distributed to Monroe County to monitor the two beaches on Lake Erie.

The MDEQ is preparing a Total Maximum Daily Load (TMDL) for Luna Pier City Beach based on historical beach closures. Although there were no closings, monitoring data collected in 2005 exceeded water quality standards and will be evaluated in the TMDL.

The MDEQ provides Clean Michigan Initiative-Clean Water Fund (CMI-CWF) and BEACH Act grants to the local health departments to aid in the implementation or enhancement of their beach monitoring programs. Local health departments request an average of $380,000 in BEACH Act funds per year from the MDEQ for local beach monitoring programs for 212 high-priority beaches. Since passage of the BEACH Act, there has been a dramatic increase in the number of monitoring and notification programs at coastal beaches in Michigan. In 2003, the number of Great Lakes beaches in Michigan that were monitored at least once a week more than doubled to 187, from 83 in 2002.

Local health departments provide beach monitoring program information to the public via press releases, brochures, beach signs, beach seminars, and Internet access. The Michigan Beach Monitoring Web site (www.deq.state.mi.us/beach) immediately provides current and historical results for *E. coli* and beach closings/ advisories as they are reported from health departments for all public beaches in Michigan. All public beaches are required to post a sign indicating whether the beach is monitored and where the results can be found.

All beach monitoring data are reported to and evaluated by the MDEQ. The MDEQ incorporates beach monitoring data into other water pollution prevention programs to encourage strategic improvements in water quality.

New York's Beach Program

New York has 321 regulated beaches located on Lake Erie, Lake Ontario, the Atlantic Ocean and Long Island Sound. All of these beaches are monitored under the BEACH Act grant. The New York State Department of Health (NYSDOH) administers the Beach Monitoring Program in conjunction with 11 subcontractors that conduct the monitoring and public notification program for the state's approximately 53 miles of regulated coastal beaches. Since 2001, NYSDOH has received $1,436,065 in grants from the U.S. EPA to help fund its beach monitoring and notification programs.

There are 21 regulated beaches in New York on Lake Erie. All of the Lake Erie beaches are monitored at least weekly for *E. coli*. A number of the beaches are also monitored for fecal coliform and enterococci. Predictive modeling is used on most Lake Erie beaches to estimate water quality conditions after significant rainfall events. In 2005 there were 81 total beach closures which occurred at 13 of 21 Lake Erie beaches. Forty-seven closures were due to an exceedence of water quality standards, while 34 closures were based on predictive modeling. A workshop is being planned for state and county program managers to review the conditions resulting in exceedences and evaluate potential remediation efforts.

Approved laboratory methods currently in use require 24 hours prior to reporting of results. While these results provide a measure of water quality at the time of sample collection, they are not necessarily indicative of water quality 24 hours later. This 24-hour lag between sampling and availability of results may have both public health implications and profound economic repercussions for beach communities. In 2006 NYSDOH will be analyzing beach samples using rapid test methodology (QPCR) that will provide results in a few hours. Validation of this new method will prove useful in the decision making process for closing and re-opening beaches.

Ohio's Beach Program

The Ohio Department of Health (ODH) has developed and continues to conduct a program for monitoring *E.coli* content at the majority of recreational waters in the state that are designated for swimming, bathing, scuba diving, or similar water contact activities. The program is implemented in partnership with the Ohio Department of Natural Resources, private/public organizations and local health departments with public bathing beaches within their jurisdictions. A total of 23 beaches are monitored along the Lake Erie shoreline. ODH has monitored many of these beaches since 1973. In 2005, 15 beaches were posted for a total of 193 days.

Since 2002, Ohio has received $901,526 in BEACH Act grant funds to develop and implement a beach monitoring and notification program at Lake Erie beaches. ODH has used BEACH Act grant funding to increase the frequency of monitoring Lake Erie beaches from twice per month to four times each week per beach. This allows for swifter identification of bacteria problems and thus shortens the time involved in notifying the public of potential health hazards. The program also highly encourages the development of localized beach water monitoring efforts, predictive models for assessing recreational water quality, pre-emptive warning systems to inform the public more effectively, and aquatic sanitation programs for identifying and eliminating potential pollution sources.

ODH provides beach water quality data, beach posting events, and information regarding its monitoring program on the department's Web site at www.odh.ohio.gov. Information on posting status is also provided through a toll-free telephone line (1-866-OHIO-BCH) for people who lack access to the Internet. BEACH Act funding also has assisted in the development of informational pamphlets that are distributed throughout the Ohio/Lake Erie area. Future funding will allow for the development of bilingual signage and other written information.

Some local health departments have instituted programs specifically to locate and eliminate failed septic systems that might contribute to high bacteria counts at public beaches. Other organizations are concentrating on controlling the migratory habits of numerous waterfowl to minimize their effects on beach water quality. Two projects funded by Ohio's Lake Erie Commission, one at Maumee Bay State Park in the western Lake Erie basin and one in the Cleveland area, are working to identify and eliminate sources of potentially harmful pathogens. Other federal, state, and local funds are being used to develop and test predictive models at five Lake Erie beaches. Predictive models use easily measured environmental and water-quality variables, like wave height and rainfall, to estimate the probability of exceeding target concentrations of bacterial indicators and thus can be used for a "nowcast" of recreational water quality. A Web-based nowcasting system for Huntington Beach will be available for public use during summer 2006. By employing intense sampling surveys and sophisticated DNA fingerprinting technologies, researchers are seeking the sources of disease-causing bacteria on Lake Erie beaches.

Pennsylvania's Beach Program

There are 12 permitted coastal recreational beaches on the southern shore of Lake Erie in Pennsylvania, 11 of which are located in Presque Isle State Park (PISP). All of the beaches are located in Erie County, which has the only coastal beaches in the Commonwealth.

Since, 2001, Pennsylvania has received $897,025 in BEACH Act grant funds to develop its beach monitoring and notification program. The Erie County Department of Health (ECDH) subcontracts with the Pennsylvania Department of Health (DOH) for funding under the BEACH Act. PISP, which is operated by the Pennsylvania Department of Conservation and Natural Resources (DCNR), is funded through an interagency agreement with the DOH. In addition to the 11 beaches at PISP, there is a permitted beach in North East Township on Lake Erie. North East Township received a portion of the EPA BEACH Act grant.

Coastal beaches in Pennsylvania are monitored using the pathogen indicators recommended by U.S. EPA. A predictive model of recreational beach water quality based on weather, known sewage discharges, storm events, and water currents is being formulated. The information would be used to see if a correlation can be established with weather and high bacterial counts. If a predictive model is established it would allow the beach managers to close beaches on a presumptive basis. This could prevent swimming in contaminated waters.

ECDH is in the process of developing a Web site to provide the public with updated information on the water quality of permitted Lake Erie beaches.

Accomplishments Related to Communication to the Public

Because it has been shown that people who engage in recreational water sports have a higher incidence of symptomatic illnesses, it has become increasingly more important to make the public aware of the potential health hazards that are associated with recreational waters. Recent progress has been made on the national and local levels to provide the public with useful tools that can provide needed information regarding the use of recreational waters. At the national level, the following public communication tools are available:

BEACH Watch

This website contains information about U.S. EPA's BEACH Program, including grants, EPA's reference and technical documents including EPA's Before You Go to the Beach brochure, upcoming meetings and events, conference proceedings, links to local beach programs, and provides access to BEACON (Beach Advisory and Closing On-line Notification), U.S. EPA's national beach water quality database. www.epa.gov/OST/beaches

Annual Great Lakes Beach Association (GLBA) Conference

In February 2001, a Great Lakes Beach Conference was held to share information on the science and technology of beach monitoring as well as research on exposure, health effects, and water quality indicators. More than 250 environmental and public health officials, beach managers, and regulators attended the three-day conference. The conclusions of the conference saw the formation of the Great Lakes Beach Association. The GLBA is comprised of members from U.S. states, Environment Canada, local environmental and public health agencies, and several universities and NGOs. The GLBA's mission is the pursuit of healthy beach water conditions in the Great Lakes area. Since 2001, the GLBA has held beach conferences annually to bring together beach managers, scientists, and agency officials to exchange information on improving recreational water quality. The next conference is planned for October 2-5, 2006, in Niagara Falls, New York, in conjunction with U.S. EPA's National Beach Conference. www.great-lakes.net/glba/

BEACHNET

An email discussion list that seeks to facilitate communication among people interested in the improvement of recreational beach water quality in the Great Lakes basin. The listserv is sponsored by the GLBA and is hosted by the Great Lakes Information Network (GLIN). Both the GLBA and the listserv are open to anyone interested in improving beach water quality, understanding bacterial contamination, developing better ways to detect and monitor pollution, or monitoring and assuring beach visitors' health. www.great-lakes.net/glba

BeachCast

This website provides Great Lakes beach goers with access to information on Great Lakes beach conditions, including health advisories, water temperature, wave heights, monitoring data, and more. BeachCast is a service of the Great Lakes Commission and GLIN. www.glc.org/announce/03/07beachcast.html

NEEAR Water Study

The National Epidemiological and Environmental Assessment of Recreational (NEEAR) Water Study is a multi-phase research study led by the CDC and U.S. EPA's Office of Research & Development and National Health and Environmental Effects Research Laboratory with assistance from USGS and the National Park Service. The study investigates human health effects associated with recreational water use. The objectives of the NEEAR Water Study are to (1) evaluate the water quality at two to three beaches per year for three years concurrently with a health study, (2) obtain and evaluate a new set of health and water quality data for the new rapid, state-of-the-art methods, and (3) develop new federal guidelines and limits for water quality indicators of fecal contamination so that beach managers and public health officials can alert the public about the potential health hazards before exposure to unsafe water can occur. The studies have been conducted at several Great Lakes beaches, including Huntington Beach in Ohio.

Adoption of Bacteria Criteria that meet National Standards

One of the provisions of the BEACH Act required coastal and Great Lakes states to adopt for their coastal recreation waters, by April 10, 2004, water quality criteria for pathogens or pathogen indicators as protective as U.S. EPA's 1986 water quality criteria for bacteria. The BEACH Act further directed U.S. EPA to propose and promulgate such standards for states that did not do so.

U.S. EPA worked collaboratively with all the states and territories that contain coastal recreation waters to identify their existing water quality standards, review them for consistency with the BEACH Act requirements, and determine what steps were needed to meet the BEACH Act requirements. On November 16, 2004, U.S. EPA published in the Federal Register a final rule that promulgated water quality standards for states and territories that had not yet adopted water quality criteria for bacteria that were as protective of human health as U.S. EPA's 1986 bacteria criteria. Information about the promulgation can be found online at: www.epa.gov/waterscience/beaches/bacteria-rule.htm

8.8 Conclusion

For persistent bioaccumulative toxic chemicals, the current weight of evidence regarding human health effects is supportive of the need for continued reductions in the levels of PBT chemicals in the environment. While public health advisories and other guidelines can be followed to protect human health from current environmental exposures, continued reductions in the level of persistent pollutants in the environment, both globally and regionally, are ultimately the most effective long-term solution to minimizing the health risks to Lake Erie basin population.

Although progress has been made in defining the health threat from Great Lakes pollutants (including Lake Erie pollutants), important issues remain requiring our diligent efforts. To protect human health in the Lake Erie basin, actions must continue to be implemented on a number of levels. The GLWQA calls for ". . . develop[ing] approaches to population-based studies to determine the long-term, low-level effects of toxic substances on human health" (IJC 1987). For the public health arena, there are a number of issues that will help to identify these long-term, low-level health effects. Research in these areas will provide a more comprehensive view of the threat to human health from environmental contaminants, and enable public health agencies to utilize this knowledge to protect the public health more effectively. A shift in priorities is now needed to prevention, intervention, and collaborative activities, including the work of LaMPs. In particular, contaminant levels monitoring in environmental media and in human tissues is an activity in particular need of support, to better quantify the extent of exposure. Health risk communication is also a crucial component to protecting and promoting human health in the basin. The LaMP can play a key role in informing people about human health impacts of environmental contaminants and what they can do to minimize their health risks. This includes linking people to information that is packaged in a variety of ways and targeted to a range of audiences, to enable people to make informed choices about their health.

Drinking Water

Over time, public water systems have been found to supply drinking water of good quality. Monitoring and corrective measures to reduce and eliminate levels of contaminants in treated water are essential components in continuing to assure the safety of drinking water supplies. As the population grows, and as more people rely on the drinking water supply from the lakes, these control measures must be adequate to reduce the risk from exposure to microbes in Great Lakes waters (Health Canada 1997). Ultimately, however, source water protection (protection of the raw waters) is the key to maintaining the good quality of drinking water supplies. The Lake Erie LaMP has designated drinking water from Lake Erie to be unimpaired but an area to protect (see Section 4).

Recreational Use

Pollution controls and remediation, such as reducing combined sewer overflows and improvements in sewage treatment, have continued to improve water quality in many areas of the Great Lakes basin in recent years. Long term planning for remediation of microbial contaminants in recreational water needs to include identification of sources of contamination, determination of which sources can be remediated and the costs involved, and timelines for implementation (Health Canada 1998a; Lake Erie LaMP 1999; U.S. EPA 1998a). Although it may not be feasible to eliminate microbial level exceedences completely in recreational waters, it is expected that as sources continue to be remediated, exceedences will continue to decline (Lake Erie LaMP 1999; U.S. EPA 1998a). The Lake Erie LaMP has designated recreational use as impaired (see Section 4).

Fish Consumption

Diet contributes over 95% of the PBT chemical intake for the general population, with drinking water, recreational water, and air constituting very minor exposure routes. Consequently, the approach by various public health agencies has been to focus on groups at higher risk of exposure to PBT chemicals from Great Lakes sources, such as high consumers of sport fish. Due to the presence of PCBs, organochlorine pesticides, mercury, and other chemicals in fish from the Lake Erie basin, fish advisories are issued that recommend restrictions on fish consumption. Tighter restrictions are recommended for pregnant women, women of childbearing age and children. When communicating health risk information to fish consumers, it is important to recognize that fish are a good source of low-fat protein. Most of the fish harvested from Lake Erie by sport and commercial fishermen meet current objectives for contaminants, and those fisheries have social, cultural and economic benefits. The Lake Erie LaMP has designated fish consumption as impaired (see Section 4).

8.9 References

ATSDR (Agency for Toxic Substances and Disease Registry). 1998. Polychlorinated Biphenyls Toxicological Profile (updated draft). Atlanta, Georgia: U.S. Department of Health and Human Services.

Al-Mufti, A.W., J.F. Copplestone, G. Kazantzis, R.M. Mahmoud and M.A. Majid. 1976. Epidemiology of organomercury poisoning in Iraq: I. Incidence in a defined area and relationship to the eating of contaminated bread. Bull. World Health Organ. 53(suppl), 23-36.

Arito, H., and M. Takahashi. 1991. Effect of methylmercury on sleep patterns in the rat. In: Advances in Mercury Toxicology. Suzuki, T., Imura, N., Clarkson, T.W., eds. New York, NY: Plenum Press, 381-394.

Baumann, P.C., W.D. Smith, and M. Ribick. 1982. Polynuclear aromatic hydrocarbon (PAH) residue and hepatic tumour incidence in two populations of brown bullheads. In: Polynuclear Aromatic Hydrocarbons: Physical and Biological Chemistry. Cooke, M.W., Dennis, A.J., and Fisher, G. eds. Batelle Press, Ohio, pp. 93-102.

Birmingham, B., A. Gilman, D. Grant, J. Salminen, M. Boddington, B. Thorpe, I. Wile, P. Tofe and V. Armstrong. 1989. PCDD/PCDF multimedia exposure analysis for the Canadian population detailed exposure estimation. Chemosphere 19(1-6): 637-642.

Bohm S., W. Karmaus, and S. Asakevich. 2001. Maternal concentration of polychlorinated biphenyls in Michigan anglers increases the risk of pre-term delivery. Am. J. Epidemiol. 153 (11): 133.

Brouwer, A., U.G. Ahlborg, M. Van Den Berg, L.S. Birnbaum, E.R. Boersma, and B. Bosveld. 1995. Functional aspects of developmental toxicity of polyhalogenated aromatic hydrocarbons in experimental animals and human infants. European Journal of Pharmacology 293: 1-40.

Buchmann, A., S. Ziegler, A. Wolf. 1991. Effects of polychlorinated biphenyls in rat liver: correlation between primary subcellular effects and promoting activity. Toxicology and Applied Pharmacology 111: 454-468.

Buck, G.M., J.E. Vena, E.F. Schisterman, J. Dmochowski, P. Mendola, L.E. Sever, E. Fitzgerald, and P. Kotyniak. 2000. Parental consumption of contaminated sport fish from Lake Ontario and predicted fecundability. Epidemiology 11, 388-393.

Buck, G.M., P. Mendola, J.E. Vena, L.E. Sever, P. Kostyniak, H. Greizerstein, J. Olson, and F.D. Stephen. 1999. Paternal Lake Ontario fish consumption and risk of conception delay, New York State angler cohort. Environ. Res. 80, S13-S18.

Buck, G.M., L.E. Sever, P. Mendola, M. Zielezny, J.E. Vena. 1997. Consumption of contaminated sport fish from Lake Ontario and time-to-pregnancy. American Journal of Epidemiology 146(11): 949-954.

Burbacher, T.M., M.K. Mohamed, and N.K. Mottett. 1988. Methylmercury effects on reproduction and offspring size at birth. Reproductive Toxicology 1(4): 267-278.

Colborn, T., F.S. vom Saal, A.M. Soto. 1993. Developmental effects of endocrine-disrupting chemicals in wildlife and humans. Environmental Health Perspectives 101(5): 378-384.

Courval, J.M., J.V. De Hoog, A.D. Stein, E.M. Tay, J.P. He, H.E. Humphrey and N. Paneth. 1999. Spot caught fish consumption and conception delay in licensed Michigan anglers. Environmental Research 80(2): S183-S188.

Courval, J.M., J.V. De Hoog, A.D. Stein, E.M. Tay, J.P. He and N. Paneth. 1997. Spot caught fish
consumption and conception failure in Michigan anglers. Health Conference '97 Great Lakes and St. Lawrence. Montreal, Quebec, Canada.

Courval, J.M., J.V. DeHoog, C.B. Holzman, E.M. Tay, L.J. Fischer, H.E.B. Humphrey, N.S. Paneth, and A.M. Sweeney. 1996. Fish consumption and other characteristics of reproductive-aged Michigan anglers - a potential population for studying the effects of consumption of Great Lakes fish on reproductive health. Toxicology and Industrial Health 12: 347-359.

Cox, C., T.W. Clarkson, D.O. Marsh, L. Amin-Zaki, S. Tikriti, and G.G. Myers. 1989. Dose-response analysis of infants prenatally exposed to methyl mercury, an application of a single compartment model to single-strand hair analysis. Environ. Res. 49(2):318-332.

Dawson, J. 2000. Hook, Line and Sinker: A profile of shoreline fishing and fish consumption in the Detroit River area. Fish and wildlife nutrition project funded by Health Canada's Great Lakes Health Effects Program.

Dellinger, J.A., S.L. Gerstenberger, L.K. Hansen, and L.L. Malek. 1997. Ojibwa health study: assessing the health risks from consuming contaminated Great Lakes fish. Health Conference '97 Great Lakes and St. Lawrence. Montreal, Quebec, Canada.

Dellinger, J.A., R.C. Meyers, K.J. Gephardt, and L.K. Hansen, L.K. 1996. The Ojibwa health study: fish residue comparisons for Lakes Superior, Michigan, and Huron. Toxicology and Industrial Health 12: 393-402.

DeVito, M.J., L.S. Birnbaum, W.H. Farland, and T.A. Gaslewicz. 1995. Comparisons of estimated human body burdens of dioxin-like chemicals and TCDD body burdens in experimentally exposed animals. Environmental Health Perspectives 103(9): 820-831.

Dewailly, E., C. Poirier, and F. Meyer. 1986. Health Hazards associated with windsurfing on polluted water. American Journal of Public Health. 76(6): 690-691.

Dufour, A. 1984. Bacterial indicators of recreational water quality. Canadian Journal of Public Health. 75(1): 49-56.

Environment Canada and U.S. EPA. 1999. State of the Great Lakes 1999. Chicago, Illinois: U.S. EPA.

Falk, C., L. Hanrahan, H.A. Anderson, M.S. Kanarek, L. Draheim, L. Needham, D. Patterson, and the Great Lakes Consortium. 1999. Body burden levels of dioxin, furans, and PCBs among frequent consumers of Great Lakes sport fish. Environmental Research 80:S19-S25.

Fein, G.G., J.L Jacobson, S.W. Jacobson, P.M. Schwartz, and J.K. Dowler. 1984. Prenatal exposure to polychlorinated biphenyls: effects on birth size and gestation age. Journal of Pediatrics 105: 315-320.

Fischbein, A., M.S. Wolff, and R. Lilis. 1979. Clinical findings among PCB-exposed capacitor manufacturing workers. Annals of the New York Academy of Sciences 320:703-715.

Fitzgerald, E.F., K.A. Brix, D.A. Deres, S.A. Hwang, B. Bush, G.L. Lambert, and A. Tarbell. 1996. Polychlorinated bipheny (PCB) and dichlorodiphenyl dichloroethylene (DDE) exposure among Native American men from contaminated Great Lakes fish and wildlife. Toxicology and Industrial Health 12: 361-368.

Fowler, B.A. 1972. Ultrastructural evidence for neuropathy induced by long-term exposure to small amounts of methylmercury. Science 175: 780-781.

Fuyuta, M., T. Fujimoto, and S. Hirata. 1978. Embryotoxic effects of methylmercuric chloride administered to mice and rats during organogenesis. Teratology 18: 353-366.

Giavini, E., M. Prati, and C. Vismara. 1983. Embryotoxic effects of 2,3,7,8-tetrachlorodibenzo-p-dioxin administered to female rats before mating. Environmental Research 31: 105-110.

Grasman, K.A., G.A. Fox, P.F.Scanlon, and J.P. Ludwig. 1996. Organochlorine-associated immunosuppression in fledgling caspian terns and herring gulls from the Great Lakes: an ecoepidemiological study. Environmental Health Perspectives. 104 (Suppl 4): 829-842.

Gray, L.E., J.S. Ostby. 1995. In utero 2,3,7,8-tetrachlorodibenzo-p-dioxin alters reproductive morphology and function in female rat offspring. Toxicology and Applied Pharmacology 133: 285-294.

Hanrahan, L.P., C. Falk, H.A. Anderson, L. Draheim, M. S. Kanarek, J. Olson, and the Great Lakes Consortuium. 1999. Serum PCB and DDE levels of frequent Great Lakes sport fish consumers - a first look. Environ. Research 80:S26-S37.

Health Canada 2000 (pg 11)

Health Canada, 1998a. Health Canada Drinking Water Guidelines. It's Your Health. Fact Sheet Series, May 27, 1997.

Health Canada. 1998b. Health-related indicators for the Great Lakes basin population: Numbers 1-20. Great Lakes Health Effects Program, Ottawa, Canada.

Health Canada. 1998c. Persistent environmental contaminants and the Great Lakes basin populations: An exposure assessment. Great Lakes Health Effects Program, Ottawa, Canada No.: H46-2198-218E.

Health Canada. 1998d. Summary: State of knowledge report on environmental contaminants and human health in the Great Lakes Basin. Great Lakes Health Effects Program, Ottawa, Canada.

Health Canada. 1998e. The health and environment handbook for health professionals. Great Lakes Health Effects Program, Ottawa, Canada No.: H46-2198-211-2E.

Health Canada. 1998f. Waterborne disease incidence study. Technical Report. Great Lakes Health Effects Program, Ottawa, Canada.

Health Canada. 1997. State of knowledge report on environmental contaminants and human health in the Great Lakes basin. Great Lakes Health Effects Program, Ottawa, Canada.

Health Canada. 1995a. Great Lakes water and your health: A summary of a Great Lakes basin cancer risk assessment: A case-control study of cancers of the bladder, colon and rectum. Great Lakes Health Effects Program, Ottawa, Canada.

Health Canada. 1993. The undiluted truth about drinking water.

Health Canada. 1992. Guidelines for Canadian recreational water quality.

Henshel, D.S. and J.W. Martin. 1995a. Brain asymmetry as a potential biomarker for developmental TCDD intoxication: a dose-response study. International Toxicologist 7(1): 11.

Henshel, D.S., J.W. Martin, R. Norstrom, and P. Whitehead. 1995b. Morphometric abnormalities in brains of Great Blue Heron hatchlings exposed in the wild to PCDDs. Environmental Health Perspectives 103(Suppl 4): 61-66.

Hovinga, M.E., M. Sowers, and H.E.B. Humphrey. 1992. Historical changes in serum PCB and DDT levels in an environmentally-exposed cohort. Archives of Environmental Contamination and Toxicology 22(4): 363-366.

Humphrey, H.E.B. 1988. Chemical contaminants in the Great Lakes: the human health aspect. In: Toxic Contaminants and Ecosystem Health: A Great Lakes Focus. Evans MS. ed. New York: John Wiley and Sons, pp. 153-165.

Humphrey, H.E.B. 1983. Population studies of PCBs in Michigan residents. In: F.M. D'Itri and M. Kamrin, (eds). PCBs: Human and environmental hazards. Boston, MA: Butterworth.

Hussain, M., J. Rae, A. Gilman, and P. Kauss. 1998. Lifetime risk assessment from exposure of recreational users to polycyclic aromatic hydrocarbons. Archives of Environmental Contamination. 35: 527-531.

Ilback, N.G. 1991. Effects of methylmercury exposure on spleen and blood natural-killer (NK) cell-activity in the mouse. Toxicology 67(1): 117-124.

Inouye, M. and U. Murakami. 1975. Teratogenic effects of orally administered methylmercuric chloride in rats and mice. Congenital Anomalies 15: 1-9.

Inouye, M., K. Murao and Y. Kajiwara. 1985. Behavioral and neuropathological effects of prenatal methylmercury exposure in mice. Neurobehavioral Toxicology and Teratology 7: 227-232.

IJC (International Joint Commission), Indicators Evaluation Task Force. 1996. Indicators to evaluate progress under the Great Lakes Water Quality Agreement.

IJC (International Joint Commission). 1987 (reprinted 1994). Revised Great Lakes Water Quality Agreement of 1978, As Amended by Protocol, Signed November 18, 1987.

Jacobson, J.L. and S.W. Jacobson. 1996. Sources and implications of interstudy and interindividual variability in the developmental neurotoxicity of PCBs. Neurotoxicology and Teratology 3: 257-264.

Jacobson, J.L., S.W. Jacobson and H.E.B. Humphrey. 1990a. Effects of exposure to PCBs and related compounds on growth and activity in children. Neurotoxicology and Teratology 12: 319-326.

Jacobson, J.L., S.W. Jacobson and H.E.B. Humphrey. 1990b. Effects of in utero exposure to polychlorinated-biphenyls and related contaminants on cognitive-functioning in young children. Journal of Pediatrics 116: 38-45.

Jacobson, S.W., G.G. Fein, J.L. Jacobson, P.M. Schwartz and J.K. Dowler. 1985. The effect of intrauterine PCB exposure on visual recognition memory. Child Development 56: 856-860.

Jacobson, J.L., S.W. Jacobson, G.G. Fein, P.M. Schwartz and J.K. Dowler. 1984. Prenatal exposure to an environmental toxin: a test of the multiple effects model. Developmental Psychology 20: 523-532.

Jacobson, S.W., J.L. Jacobson, P.M. Schwartz, and G.G. Fein. 1983. Intrauterine exposure of human newborns to PCBs: measures of exposure. In: F.M. D'Itri and M. Kamrin, (eds). PCBs: Human and Environmental Hazards. Boston, MA: Butterworth.

Johnson, B.L., H.E. Hicks, D.E. Jones, W. Cibulas, A. Wargo and C.T. De Rosa. 1998. Public health implications of persistent toxic substances in the Great Lakes and St. Lawrence basins. Journal of Great Lakes Research 24 (2): 698-722.

Johnson, B.L.and D.E. Jones. 1992. ATSDR's activities and views on exposure assessment. Journal of Exposure Analysis and Environmental Epidemiology 1: 1-17.

Kociba, R.J., D.J. Keyes and J.E. Beyer. 1978. Toxicologic studies of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in rats. Toxicology of Occupational Medicine 4: 281-287.

Kreiss, K. 1985. Studies on populations exposed to polychlorinated biphenyls. Environmental Health Perspectives 60: 193-199.

Lake Erie LaMP. 1999. Recreational Water Quality Impairments (Bacterial Levels and Beach Postings). Beneficial Use Impairment Assessment. Lake Erie Lakewide Management Program.

Lake Erie LaMP. 1999. Lake Erie LaMP Status Report 1999. Lake Erie Lakewide Management Program.

Leatherland, J.F. 1992. Endocrine and reproductive function in Great Lakes salmon. In: Chemically-induced alterations in sexual and functional development. Colborn, T., Clement, C., [eds]: the wildlife/human connection. Chapter 7, Vol. 21. Princeton, New Jersey: Princeton Scientific Publishing Company, Inc.

Lonky, E., J. Reihman, T. Darvill, J. Mather and H. Daly. 1996. Neonatal behavioral assessment scale performance in humans influenced by maternal consumption of environmentally contaminated Lake Ontario fish. Journal of Great Lakes Research 22(2): 198-212.

Magos, L., A.W. Brown and S. Sparrow. 1985. The comparative toxicology of ethyl and methylmercury. Archives of Toxicology 57: 260-267.

Magos, L.and W.H. Butler. 1972. Cumulative effects of methylmercury dicyandiamide given orally to rats. Food and Cosmetics Toxicology 10: 513-517.

Magos, L., G.C. Peristianis, and T.W. Clarkson. 1980. The effect of lactation on methylmercury intoxication. Archives of Toxicology 45: 143-148.

McConnell, E.E., J.A. Moore and D.W. Dalgard. 1978. Toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin in rhesus monkeys following a single oral dose. Toxicology and Applied Pharmacology 43: 175-187.

McNulty, W. 1984. Fetotoxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) for Rhesus macaques. American Journal of Primatology 6: 41-47.

Mendola, P., G.M. Buck, J.E. Vena, M. Zielezny and L.E. Sever. 1995. Consumption of PCB-
contaminated sport fish and risk of spontaneous fetal death. Environmental Health Perspectives 103(5):498-502.

Menzer, R.E. and J.O. Nelson. 1980. Water and soil pollutants. In: Casarett and Doull's Toxicology, The Basic Science of Poisons. Doull, J., Klaassen, C.D., Amdur, M.A., eds. Second edition. Chapter 25.

Mergler, D., S. Belanger, F. Larrible, M. Panisset, R. Bowler, J. Lebel and K. Hudnell. 1997. Early nervous system dysfunction in adults associated with eating fish from the St. Lawrence River system. Health Conference '97 Great Lakes and St. Lawrence. Montreal, Quebec, Canada.

Mitsumori, K., M. Hirano and H. Ueda. 1990. Chronic toxicity and carcinogenicity of methylmercury chloride in B6C3F1 mice. Fundamentals of Applied Toxicology 14: 179-190.

Mitsumori, K., K. Maita and T. Saito. 1981. Carcinogenicity of methylmercury chloride in ICR mice: preliminary note on renal carcinogenesis. Cancer Letters 12: 305-310.

Mohamed, M., T. Burbacher and N. Mottet. 1987. Effects of methyl-mercury on testicular functions in Macaca fascicularis monkeys. Pharmacology and Toxicology 60(1): 29-36.

Newhook, R.C. 1988. Polybrominated Biphenyls: Multimedia Exposure Analysis. Contract report to the Department of National Health and Welfare, Ottawa, Canada.

Nolen, G.A., E.V. Buchler and R.G. Geil. 1972. Effects of trisodium nitrotriacetate on cadmium and methylmercury toxicity and teratogenicity in rats. Toxicology and Applied Pharmacology 23: 222-237.

NRDC. 2003. Table: Pathogens and Swimming associated Illnesses.

NTP (National Toxicology Program). 1982. Carcinogenesis Bioassay of 2,3,7,8-Tetrachlorobdibenzo-p-dioxin in Osborne-Mendel Rats and B6C3F1 Mice (gavage study). (NIH) DHHS publication no 82-1765.

O'Connor, D.R. 2002. Part Two Report of the Walkerton Inquiry. Queen's Printer for Ontario.

Ontario Ministry of Environment. 1999. Mercury in fish: a special advisory for women of childbearing age and children under 15. March 1999.

Ontario Ministry of the Environment. 2004. White Paper on Watershed-based Source Protection Planning. Queen's Printer for Ontario.

Sargent, L.M., G.L. Sattler and B. Roloff, 1992. Ploidy and specific karyotypic changes during promotion with phenobarbital, 2,5,2',5'-tetrachlorobiphenyl, and/or 3,4,3',4'-tetrachlorobiphenyl in rat liver. Cancer Research 52: 955-962.

Schantz, S.L., A.M. Sweeney, J.C. Gardiner, H.E.B. Humphrey, R.J. McCaffrey, D.M. Gasior, K.R. Srikanth and M.L. Budd. 1996. Neuropsychological assessment of an aging population of Great Lakes fish eaters. Toxicology and Industrial Health 12: 403-417.

Schantz, S.L., J. Moshtaghian and D.K. Ness. 1992. Long-term effects of perinatal exposure to PCB congeners and mixtures on locomotor activity of rats. Teratology 45: 524-530.

Schantz, S.L.and R.E. Bowman. 1989. Learning in monkeys exposed perinatally to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Neurotoxicology and Teratology 11: 13-19.

Schwartz, P.M., S.W. Jacobson, G. Fein, J.L. Jacobson and H.A. Price. 1983. Lake Michigan fish consumption as a source of polychlorinated biphenyls in human cord serum, maternal serum, and milk. Public Health Briefs 73: 293-296.

Seyfried, P., R. Tobin, N. Brown, and P. Ness. 1985b. A prospective study of swimming-related illness. I. Swimming-associated health risk. American Journal of Public Health. 75(9): 1068-70.

Seyfried, P., R. Tobin, N. Brown and P. Ness. 1985b. A prospective study of swimming-related illness. II. Morbidity and the microbiological quality of water. American Journal of Public Health. 75(9): 1071-1075.

Smith, B.J. 1984. PCB levels in human fluids: Sheboygan Case Study. Technical Report WIS-SG-83-240. University of Wisconsin Sea Grant Institute, Madison, Wisconsin.

Stellman, S.D., M.V. Djordjevic, J.E. Muscat, L. Gong, D. Bernstein, M.L. Citron, A. White and M. Kemeny. 1998. Relative abundance of organochlorine pesticides and polychlorinated biphenyls in adipose tissue and serum of women in Long island, New York. Cancer Epidemiol. Biomarkers Prev. 7, 489-496.

Stewart, P., T. Darvill, E. Lonky, J. Reihman, J. Pagano and B. Bush. 1999. Assessment of prenatal exposure of PCBs from maternal consumption of Great Lakes fish. Environmental Research 80(2): 587-596.

Stone, R. 1992. Swimming against the PCB tide. Science 255: 798-799.

Stow, C.A., S.R. Carpenter and L.A. Eby. 1995. Evidence that PCBs are approaching stable concentrations in Lake Michigan fishes. Ecological Applications 5(1): 248-260.

Swain, W.R. 1991. Effects of organochlorine chemicals on the reproductive outcome of humans who consumed contaminated Great Lakes fish: an epidemiologic consideration. Journal of Toxicology and Environmental Health 33(4): 587-639.

Tarvis, D., K. Hegmann, S. Gerstenberger, L. Malek, and Dellinger, J. 1997. Association of mercury and PCB levels with chronic health effects in Native Americans. Health Conference ’97 Great Lakes and St. Lawrence. Montreal, Quebec, Canada.

Taylor, P.R., J.M. Stelma, and C.E. Lawrence. 1989. The relation of polychlorinated biphenyls to birth weight and gestational age in the offspring of occupationally exposed mothers. American Journal of Epidemiology 129: 395-406.

Tryphonas, H. 1995. Immunotoxicity of PCBs (aroclors) in relation to Great Lakes. Environmental Health Perspectives 103 (Suppl 9): 35-46.

Tsubaki, T., and H. Takahashi. 1986. Recent advances in Minamata disease studies. Kodansha, Ltd., Tokyo, Japan.

U.S. EPA. 1999. EPA action plan for beaches and recreational waters: Reducing exposures to waterborne pathogens. EPA600R-98/079. March 1999. http://www.epa.gov/OST/beaches.

EPA. 1998. BEACH Action Plan. EPA/600/R-98/079.

U.S. EPA. 1999a. Office of Drinking Water and Ground Water Home Page, Website at http://www.epa.gov/safewater/about.html , Revised December 2, 1999.

U.S. EPA. 1986. Ambient water quality criteria for bacteria, 1986.

U.S. EPA and Environment Canada. 1995. The Great Lakes: An Environmental Atlas and Resource Book.

Vo, M.T., B.M. Hehn, J.D. Steeves, and D.S. Henshel. 1993. Dysmyelination in 2,3,7,8-tetrachlorodibenzo-p-dioxin exposed chicken embryos. Toxicologist 13(1):172.

Whitman, R., A. Gochee, W. Dustman, and K. Kennedy. 1995. Use of coliform bacteria in assessing human sewage contamination. Natural Areas Journal. 15:227-233.

World Health Organization. 1998. Guidelines for safe recreational water environments: Coastal and fresh-water.

World Health Organization. 1984. Definition of Health. Geneva.

Yasutake, A., Y. Hirayama, and M. Inouye. 1991. Sex differences of nephrotoxicity by methylmercury in mice. In: Bach, P.H., et al., eds. Nephrotoxicity: mechanisms, early diagnosis, and therapeutic management. Fourth International Symposium on Nephrotoxicity. Guilford, England, UK, 1989. New York, NY: Marcel Dekker, Inc., 389-396.

Section 9: Remedial Action Plans and Watershed Implementation

9.1 Introduction

In addition to the development of LaMPs, Annex 2 of the Great Lakes Water Quality Agreement called for the development of Remedial Action Plans (RAPs) for the most environmentally degraded Areas of Concern (AOCs) around the Great Lakes. There are 12 AOC in the Lake Erie basin: two binational, one Canadian and nine U.S. The RAPs have a smaller geographic focus than the LaMP, often encompassing only part of a watershed, and focus on restoring locally impaired beneficial uses. Implementation of remedial actions has been underway in most RAPs for over twelve years, using a combination of federal, state, provincial and local resources. The restoration of the AOCs will help to improve Lake Erie, and actions to restore Lake Erie will often benefit the AOCs. It is essential for the Lake Erie LaMP to continue to cultivate communication with the RAPs and to benefit from the successful partnerships and programs that the RAPs have already created. In many ways the success of the LaMP depends on the success of the RAPs.

Source track-down conducted for the LaMP identified the AOCs, as well as certain other watersheds,as key source areas and also where remediation could most benefit the lake. Land use management practices in particular have a significant impact on tributary loading to the lake. Therefore, the LaMP will focus on implementing management actions in the AOCs and at the watershed level as the primary steps towards restoring beneficial uses to the lake.

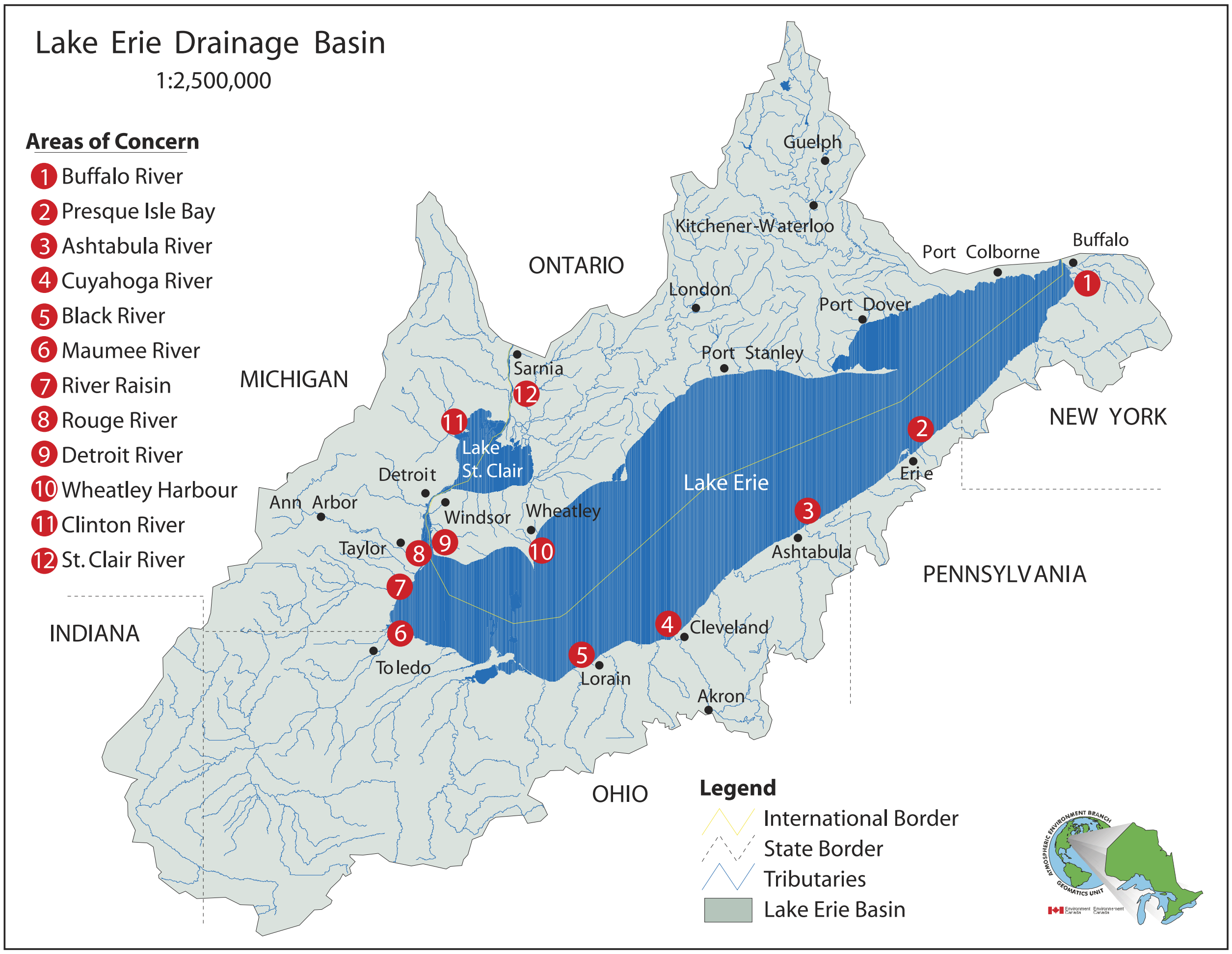


Figure 9.1: Areas of Concern in the Lake Erie drainage basin

The watershed is widely regarded as an appropriate unit to manage natural resources. As part of the Lake Erie LaMP process, the Fuzzy Logic model developed by and for the Lake Erie LaMP identified land use as the single biggest driver of in-lake conditions (Colavecchia et al. 2000). Watershed management focuses on land use and the sources of contaminants that are associated with land based activities. On a broader scale, Justice O'Connor's reports stemming from the Walkerton, Ontario tragedy reaffirmed the importance of watershed management. He focused many of his recommendations on mechanisms to strengthen and institutionalize watershed management through Source Water Protection Plans for drinking water in Ontario as a means to protect human health and the environment.

There are many watershed based projects underway around the Lake Erie basin, however, as with the RAPs, most of them are designed to address problems in that watershed and do not address potential impacts to Lake Erie. As the Lake Erie LaMP progresses, the LaMP partners will continue to assess these existing watershed projects encouraging better connections between the watersheds and the overall state of the lake. Watershed action plans and Total Maximum Daily Load plans (TMDLs) underway in the U.S. will be important to follow and coordinate with. In Ontario, the Conservation Authorities' initiatives in support of watershed-based source water protection in the Lake Erie basin will provide critical information that can be used to address the stresses imposed on the lake by adverse conditions in key tributaries.

The following sections highlight the major activities completed or underway in the Lake Erie AOCs and several selected watersheds. Note that these activities are only a small representation of the ongoing watershed work throughout the basin. For the most part, these updates cover only those actions implemented or initiated since the Lake Erie LaMP 2004 Report was published. Table 9.1 provides a "snapshot" of the AOC and watershed programs. In the future, this section will continue to expand the presentation of accomplishments in other watersheds as they become more focused on implementation of management efforts to assist in achieving the goals of the Lake Erie LaMP.

9.2 Remedial Action Plan Updates

Buffalo River RAP, New York

www.fbnr.org
www.epa.gov/glnpo/aoc/buffalo.html

History

The Buffalo River RAP process was originally developed as a partnership among U.S.EPA, the New York State Department of Environmental Conservation (NYSDEC) and the Buffalo River Citizens' Committee. The committee was established by NYSDEC in 1987 and is made up of representatives from community, environmental, academic, sporting, and local government interests. The AOC includes the lower 6.2 miles of the river (10km). The combined Stage 1 and Stage 2 RAP was completed in November 1989 as a working document. RAP status reports have been published since 1991 to update commitments, track implementation, and celebrate accomplishments.

Remedial activity efforts have been focused on six major areas: stream water quality monitoring; river bottom sediments; inactive hazardous waste sites; municipal and industrial wastewater treatment facilities; combined sewer overflows; and fish and wildlife habitat. Strategies and remedial activity progress are updated annually in the Buffalo River RAP Status Report produced by the Buffalo Niagara Riverkeepers. There are five BUIs in the AOC: fish and wildlife consumption advisories; the presence of fish tumors; degraded benthos; dredging restrictions; and loss of fish and wildlife habitat.

Progress since 2004 LaMP Report

The Buffalo Niagara Riverkeepers (BNR), formerly the Friends of the Buffalo Niagara Rivers, have received U.S.EPA-GLNPO funding to continue RAP coordination. The focus is on research, priority project implementation, and restoring the beneficial uses through delisting considerations. The RAP process assesses project costs for implementation. The BNR is conducting RAP reporting and project management including: the Buffalo River

Sediment Remediation Feasibility Study; the City of Buffalo's waterfront revitalization; and the Buffalo Sewer Authority's CSO correction. The Buffalo Sewer Authority's draft LTCP for CSO abatement is currently under review by NYSDEC and will be included in the city's SPDES permit once the LTCP is approved.

Other projects address data gaps and needs to reduce nonpoint sources, restore habitat, and improve the watershed's open space areas. Three habitat improvement projects have been constructed to address habitat impairments with funding provided through U.S.EPA. Coordination involved Erie County, the City of Buffalo, USFWS, USACE, and NYSDEC. A Sediment Remediation Feasibility Study is underway by the USACE, U.S.EPA, NYSDEC and the BNR to characterize the extent and spatial distribution of priority contaminants within river sediments between the inner harbor upstream to the confluence of Buffalo Creek and Cazenovia Creek.

In addition, a Report Card has been developed that clearly defines environmental categories (e.g. water quality, land use), successes and improvements, current conditions, steps for resolution, and applies a grade and trend rating the current status. The 2005 Buffalo River RAP Status Report is posted on the BNR website.

Next Steps

- Under the leadership of the BNR, the revitalized Remedial Action Committee (RAC) has federal funding to continue RAP implementation. An organizational structure involving an executive committee with four working groups is leading the RAP to address: 1) project implementation – beneficial use assessment and evaluation; 2) RAP reporting; 3) remedial strategies and monitoring; and 4) public outreach and involvement.
- Delisting criteria are under further development. Beneficial Use Assessment (BUA) studies are planned or already underway for several indicators. The BUA workgroup notes conducting successful planning meetings and development of a contract to conduct a herpetological study in 2006. An algae and phytoplankton study is planned, and a staff biologist is to be hired to assist in habitat assessment.
- A volunteer River Watcher program is underway to report observations to the BNR. The watchers are to assist in evaluating the visibility of the Buffalo River and formation of a Remedial Strategy Workgroup for the AOC.
- The Valley Community Association has received a loan to address riverfront property restoration.
- The City of Buffalo, BNR and Buffalo River Planning are to submit a grant application to the New York State Department of State Brownfield Opportunity Area program for restoration of 500 acres in the Buffalo River corridor. The City has already received funding for an area south of the river to Lackawanna.
- The City of Buffalo's Good Neighbor Planning Alliance has requested BNR to assist in the development of a plan related to brownfields and waterfront issues.
- The Buffalo River Greenway Implementation Plan will be completed soon. Separate partnership efforts with the Land Conservancy and Trust for Public Land are working on land acquisitions and easements to address waterfront parcels.
- Continue developing the Sediment Remediation Feasibility Study and identify alternative sources of funding for remediation.
- NYSDEC stocked several thousand walleye into the Buffalo River in 2005 and will continue to evaluate the potential for long-term restoration of the valuable sport fishery.
- Negotiations continue with the Buffalo Sewer Authority and upstream municipalities to address CSO/SSO abatement and elimination plans.
- The Erie County Soil & Water Conservation District is working with municipalities and private landowners on riparian buffer activities to reduce soil erosion and nutrient loading from upper watershed areas. SUNY Buffalo and SUNY College at Buffalo are collaborating on finalizing a sediment transport model for the watershed.

Presque Isle Bay RAP, Pennsylvania
www.epa.gov/glnpo/aoc/presque.html

History

Located in the northwest corner of Pennsylvania on the southern shore of Lake Erie, Presque Isle Bay is a 3718 acre (1505 hectare) natural embayment formed by a 7 mile long (11.3 km) re-curved sand spit. Over 80% of the bay's watershed is comprised of urban and industrial land uses in the City of Erie and its outlying townships. As a relatively closed system with a hydrologic detention time of almost 2.5 years, Presque Isle Bay tends to act as a natural "settling basin" for sediment entering its waters. Given the urban nature of the majority of the watershed, much of this sediment is contaminated with heavy metals and various organic compounds. Presque Isle Bay was designated as the 43rd Great Lakes Area of Concern by the US Department of State in 1991. The Pennsylvania Department of Environmental Protection (PADEP) examined over 3100 brown bullhead catfish from the bay. Histopathology confirmed an external tumor rate of 64% and a liver tumor rate of 22%. A Stage 1 Report submitted to the IJC in 1993 listed the BUIs of fish tumors or other deformities and restrictions on dredging.

A sediment study completed by Battelle Ocean Sciences in 1997 suggested that the implementation of source control measures in the watershed may be sufficient to allow for natural recovery of bay sediments. Gannon University provided results of a sediment investigation conducted jointly with U.S.EPA in 2000. The study utilized a "triad" sampling approach entailing sediment chemical sampling for metals and PAHs, benthic macroinvertebrate assemblage analysis, and sediment toxicity testing. Sediment dioxin/furan levels were also analyzed at the request of the PAC. Metals and PAH results generally supported earlier Battelle findings of widespread, low-level contamination without identifiable hot spots. Due to lack of screening criteria in Pennsylvania, dioxin/furan results were compared to New York state sediment screening criteria. Concentrations of these compounds were below human health screening levels but exceeded wildlife screening criteria. Based on these preliminary findings, PADEP analyzed fish tissue from six resident bay species in 1991 and found the dioxin/furan tissue burden to be well below advisory levels.

Since 1989, the City of Erie has spent over $100 million to upgrade its sewage system. Many CSOs that contributed up to 50 million gallons per day of untreated sewage to the bay were eliminated. In 1991, a large coal-fired power plant (a source of metals and PAHs) along the bayfront was decommissioned and converted to a library and museum. The rest of Erie's bayfront was undergoing a dramatic transformation from a highly industrialized corridor to a recreational, residential and light commercial zone. Perhaps not surprisingly, these changes corresponded to dramatic improvements in the health of the Bay's brown bullhead population. Longitudinal monitoring of these bottom-feeding fish has shown that between 1992 and 1999, the frequency of external tumors has declined from 64% to 17%, and the frequency of liver tumors has declined from 22% to 0%.

In December, 2002, Presque Isle Bay became the first U.S. AOC to attain the "AOC in Recovery Stage" designation. In addition to celebrating the hard work and environmental ethic of the Erie community, this milestone marked a shift in PADEP's focus from assessment and remedial action to monitoring, pollution prevention, and the development of delisting targets for the Bay's BUIs.

Progress since 2004 LaMP Report

Brown bullhead monitoring has continued annually in Presque Isle Bay. Bullhead are collected and examined for grossly observable external lesions, and a subsample of fish is necropsied for histopathological analysis. Tissue samples are sent to the USGS Leetown (WV) Laboratory for histological analysis of external and liver lesions. Preliminary monitoring results to date suggest that bullhead lesion rates have remained stable during the Recovery Stage period. Data are currently undergoing statistical analysis.

PADEP initiated a study in 2004 to determine the background (reference) incidence rate of brown bullhead lesions in Lake Erie. Samples were collected from non-AOC reference sites in New York, Pennsylvania and Ohio and evaluated in accordance with the methodology developed for Presque Isle Bay. These same locations were re-sampled in 2005. Final results are expected in early 2006. The results of this work will be used to support the development of appropriate delisting targets for the Fish Tumors or Other Deformities BUI.

Pennsylvania Sea Grant has funded several lines of research to better understand the environmental biology and ethology of the Bay's brown bullhead population. This ongoing research includes: 1) A study by Gannon University to sample the deeper, open waters of the Bay to better understand seasonal brown bullhead migration patterns and the dynamics of bullhead exposure to contaminated sediment; 2) A study of the reproductive success of brown bullhead in Presque Isle Bay by sampling young-of-year bullhead and tracking recruitment into the population; and 3) Genetic research to determine the extent to which the Bay's *Ameiurus* species hybridize and the potential relationship between bullhead genetics and the elevated tumor incidence rate in this fish population.

With funding from U.S.EPA-GLNPO, the PADEP and Pennsylvania Sea Grant have held a series of workshops to: 1) evaluate the historical sediment contamination in the Bay; 2) develop a comprehensive sediment sampling program to augment historical data; and 3) develop appropriate delisting targets for the Restrictions on Dredging BUI. Experts from U.S.EPA, USGS, NOAA and several state agencies have participated at these workshops along with the Bay's PAC sediment subcommittee. Final delisting targets will be proposed by PADEP following the review and analysis of the comprehensive sediment sampling results by the experts.

In September 2005, PADEP partnered with PA Sea Grant, Gannon University, the Erie County Department of Health, the Regional Science Consortium at the Tom Ridge Center at Presque Isle Bay, and MacDonald Environmental Services, Ltd. to implement the comprehensive sediment sampling program developed during the sediment BUI workshops mentioned above. More than 50 surficial and sediment core samples were collected from Presque Isle Bay to characterize both the current and historical levels of sediment contamination. The U.S.EPA research vessel, The Mudpuppy, assisted with the collection of sediment cores. Both chemical and toxicological analyses are being conducted. The results of the study are expected in early 2006.

PADEP's Coastal Resources Management Program funded a 2005 study by the Erie County Department of Health to sample suspended sediment quality in major tributaries to Presque Isle Bay. Results are expected in 2006.

Next Steps

- The final Fish Tumor and Other Deformities BUI workshop is planned for February 2006. Experts from the U.S.EPA, USGS, academia, state agencies, and elsewhere will meet with PADEP and the Bay's PAC fish subcommittee to discuss bullhead monitoring results to date. Important outcomes from this series of workshops will include standardized bullhead sampling, necropsy, and analysis protocols and the development of updated AOC delisting targets for this BUI.
- The final Restrictions on Dredging BUI workshop is planned for 2006. Sediment experts will meet once again with PADEP and the Bay's PAC sediment subcommittee to discuss their analysis of available sediment quality data and make recommendations regarding appropriate delisting targets. Final targets will be proposed by PADEP following the evaluation of the comprehensive sediment sampling results and analysis of data by the experts.
- PADEP, in partnership with Pennsylvania Sea Grant and MacDonald Environmental Services, Ltd. plans to present a series of papers at IAGLR 2006 regarding the development and application of delisting criteria for Great Lakes AOCs based on the work done in Presque Isle Bay.
- PADEP has partnered with Pennsylvania Sea Grant to seek funding to develop a comprehensive management plan for the Bay watershed and develop an on-line library of literature related to the AOC.
- PADEP plans to host a summit of Lake Erie RAP, watershed and LaMP groups in 2006.

Ashtabula River RAP, Ohio
www.epa.gov/glnpo/aoc/ashtabula.html

History

The Ashtabula River is located in far northeastern Ohio. Years of unregulated discharge and mismanagement of wastes along the river and Fields Brook (a superfund site) seriously contaminated sediments and degraded biological communities. The lower two miles of the river encompass the AOC. The Ashtabula River RAP process began in 1988 with the establishment of the Ashtabula River RAP Advisory Council. The 1991 Stage 1 Report documented six beneficial use impairments, all related to contaminated sediment. These included: restrictions on fish and wildlife consumption; degradation of fish and wildlife populations; fish tumors or other deformities; degradation of benthos; restrictions on dredging; and loss of fish and wildlife habitat. PCBs are the major contaminant driving the cleanup, but mercury, PAHs, low level radionuclides and other chlorinated organics are also of concern. An interim dredging project in 1993 removed several feet of relatively uncontaminated sediments to keep the recreational navigation channel open.

The Ashtabula River Partnership (ARP) was created in 1994 to serve as a more formally structured, concentrated effort to get the river dredged. As an alternative to the impending designation of the river as an extension of the Fields Brook superfund site, the ARP's goal was to look beyond traditional approaches to determine a comprehensive solution for remediating contaminated sediments and restoring beneficial uses. An oversight committee and several technical committees were established and a local coordinator was hired. The nonprofit Ashtabula River Foundation was incorporated in 1997 to manage financing for the river cleanup.

Since 1990, extensive sediment characterization studies have been implemented to: map concentrations of pollutants (particularly PCBs); estimate sediment volume to be removed; delineate PAH distribution; ensure sediments did not qualify as hazardous waste; screen for low level radioactive waste; and model sediment transport, scouring and deposition rates. A creative mix of funding from local partners, U.S.EPA, US Army Corps of Engineers (USACE), GLNPO, Ohio EPA and potentially responsible parties funded the above studies and the preparation of a comprehensive management plan and environmental impact study (CMP/EIS). Extensive reviews of all agencies' authorities were conducted to determine critical decision points and whose responsibility they would be.

Progress since 2004 LaMP Report

The Comprehensive Management Plan/EIS for river dredging was approved by the USACE.

A 50 acre upland site was purchased for construction of the landfill facility.

Water quality target criteria to achieve during the dewatering process have been identified and a monitoring plan to ensure environmental protection during the dredging and dewatering has been developed.

The primary federal funding source for river dredging had been expected to be the USACE under WRDA 312 and operation and maintenance (O&M) authorities. However, uncertainties in the federal budget prompted the ARP to apply for newly authorized Great Lakes Legacy Act (GLLA) funding as well. Under this scenario, Legacy Act funds would be used to remediate the more contaminated upstream area, while USACE funds would be used in the downstream portion that currently supports commercial navigation. Approval of $25 million in GLLA funding was announced on December 12, 2005.

Federal and state natural resource trustees began work on a formal Part B assessment on behalf of an Ashtabula River natural resource damage claim under CERCLA authority. Sampling was done for water quality, fish tissue and community and sediment.

Next Steps

- Construction of the landfill will begin in 2006. Dredging will begin as soon as the landfill is ready. Additional coordination will continue with the Corps to dredge the lower, less contaminated area of the river. Once the contaminated sediments have been removed, monitoring will be needed to determine if the cleanup has been sufficient to restore beneficial uses. Additional habitat restoration may be needed.

- Several habitat restoration projects funded under an NRDA settlement related to the Fields Brook Superfund site are planned for the river.

Cuyahoga River RAP, Ohio

www.cuyahogariverrap.org
www.epa.state.oh.us/dsw/rap/cuyahog.html
www.epa.gov/glnpo/aoc/cuyahoga.html

History

The Cuyahoga River RAP Coordinating Committee, representing multiple sectors, was appointed by the Ohio EPA in 1988. The non-profit Cuyahoga River Community Planning Organization (CRCPO) was formed to receive funds and provide local staff to support RAP activities. The AOC covers the lower 45 miles of the river and 10 miles of shoreline from Edgewater Park to Wildwood Park. The 1992 Stage 1 Report identified 10 beneficial use impairments including: restrictions on fish consumption; degradation of fish populations; fish tumors or other deformities; degradation of benthos; restrictions on dredging activities; eutrophication; beach closings; degradation of aesthetics; and loss of fish and wildlife habitat. Several update reports have been prepared since the 1992 report.

The Cuyahoga was named an American Heritage River (AHR) in 1998. Although the AHR program covers the entire river and the RAP only the lower portion, the two initiatives work together to leverage the resources needed to improve the river. Over the past several years, the RAP has worked to break the AOC down into smaller watershed units and establish individual watershed stewardship groups. There are six groups to date. The RAP is also participating in the TMDL development and implementation in the lower river. The RAP worked with the Ohio EPA to develop and adopt water quality standards for the navigation channel as part of the first step in what became a phased TMDL process for the river. Over the years, the Cuyahoga RAP has hosted workshops and conferences, prepared numerous educational brochures and guides, implemented a number of habitat restoration projects, completed a wetland location and categorization inventory to provide options for mitigation and protection within the AOC, fostered adoption of conservation easements, and worked with several local initiatives to preserve green space and better tie environmental protection with economic development. Field studies have also been done to better characterize fish communities, habitat needs and sediment contaminant quantification, particularly in the navigation channel of the river.

Progress since 2004 LaMP Report

Follow-up studies to the 2003 approved TMDL for the lower river are underway. These include a stressor identification study for Tinker’s Creek, and a feasibility study for the removal of the Rt. 82 dam. Following several studies to improve the dissolved oxygen levels and habitat in the navigation channel, the RAP is pursuing options to install fish habitat units along/behind the sheet piling lined riverbanks. The RAP has begun a reassessment of BUIs on a subwatershed basis and as compared to the Ohio Delisting Targets for AOCs.

In 2005 the RAP and partners conducted further assessment of wetlands in the AOC to measure their quality to provide the basis for prioritizing protection and restoration. Several RAP partners also completed a Community Riparian and Wetland Guidance manual providing guidance on the utility of local setback ordinances. These partners also produced a detailed brochure on the advantages of conservation easements, how to establish them and the current organizations holding them for the entire U.S. Lake Erie watershed.

Upstream of the AOC, the Kent Dam was redesigned to improve flow and eliminate stagnant upstream pools as well as create a challenging passage for kayakers and a riparian park. The Munroe Falls dam was also removed uncovering a natural succession of smaller falls. These dam removals as well as others anticipated further downstream are helping to restore the natural hydrology of the Cuyahoga River.

Next Steps

- Both Akron and Cleveland have approved plans for the long term removal of CSOs, but it will be 20 to 30 years before all construction is completed.
- Further improvement in river conditions from sediment and non-point source reductions is expected as Phase II Storm Water Management Plans are implemented by permitted communities within the AOC. These communities are required to adopt local measures to control storm water runoff from construction activities and municipal operations, remove illicit discharges, and institute public education and involvement activities by early 2008.
- The RAP continues to work with various other local initiatives to better connect economic advancements and environmental improvements.
- Additional progress in restoring beneficial uses within the AOC can only continue with the support of local community watershed groups dedicated to providing stewardship of their local tributary streams. The RAP and its partners continue to support groups that have formed in Euclid Creek, Doan Brook, West Creek, Mill Creek and Pond Brook. New watershed groups are in the process of being established in Big Creek, Yellow Creek, Tinkers Creek and Chippewa Creek with the assistance of the RAP and its partners. Many of these groups have or will complete watershed action plans for their tributary streams over the next several years.
- Under WRDA 2006, $500,000 was budgeted for the Corps of Engineers to work with the Cuyahoga RAP and partners to develop and test a “high performance shoreline management system” (green bulkhead) prototype along the Cuyahoga River ship channel. The RAP has been working for many years to re-establish some habitat along the largely bulkheaded ship channel.

Black River RAP and Watershed Initiative, Ohio

www.epa.state.oh.us/dsw/rap/blk_home.html
www.epa.gov/glnpo/aoc/blackriver.html
www.noaca.org/blkrap.html
www.blackriverwatershed.org

History

The Black River RAP process began in 1991 with the establishment of the Black River Coordinating Committee (BRCC) by Ohio EPA. The group represents a diverse membership and plays an active role in development and implementation of the RAP, not just an advisory role. Originally, the AOC included only the lower mainstem, due to many industrial operations and wastewater treatment plant discharges. Sediments had been contaminated with PAHs from a steel mill coking facility and there was a high incidence of fish tumors. Prior to the initiation of the RAP process, many of the discharges had been discontinued or remediated. Due to increasing pressure from non-point sources, the BRCC expanded the AOC boundaries to include the entire watershed, which is largely agricultural and rural. The PAH contaminated sediments were removed in 1990 under an enforcement action. The 1994 Stage 1 RAP identified 10 beneficial use impairments including: restrictions on fish and wildlife consumption; degradation of fish and wildlife populations; fish tumors or other deformities; degradation of benthos; restrictions on dredging; eutrophication; restrictions on drinking water consumption; beach closings; degradation of aesthetics; and loss of fish and wildlife habitat.

The RAP adopted a Riparian Corridor Resolution in 1996 that outlined the need for riparian corridor establishment and protection. A Strategic Long Range plan was developed in 1997. The RAP received national attention with the construction of a fish habitat shelf along the lower river at the Black River Landing brownfield remediation site. Since its construction, a dramatic improvement has been seen in the local fish community structure. In partnership with the US Army Corps of Engineers under a WRDA 401 project, the RAP participated in the development of French Creek specific watershed guide to assist landowners and elected officials in making decisions that better protect the environment and the creek. This was the RAP’s first product in its attempt to tackle nonpoint source issues by breaking the AOC down into subwatersheds.

Progress since 2004 LaMP Report

Since the remediation of the PAH-contaminated sediments, the incidence of tumors and other deformities in fish in the lower river has continued to decline. On Earth Day 2004, the tumor BUI status was changed from impaired to "in recovery". The contact advisory listed in 1983 was also rescinded that day. Benthic communities in the East Branch have improved dramatically. All areas now meet Ohio EPA warmwater habitat biological criteria for benthos, and some areas are approaching exceptional warmwater habitat criteria. This portion of the AOC is under considerable development pressure and in need of protection. The Black River RAP decided a formal delisting of the benthos impairment for the East Branch would be the best method to publicize the improvement and garner local support to protect the waterway. U.S.EPA approved the delisting for this BUI in 2005.

Improvements in wastewater treatment plant discharges along the East Branch also led to significant reduction in algal growth downstream from the Grafton wastewater treatment plant.

In the fall of 2004, the Black River RAP received the Lake Erie Award from the Ohio Lake Erie Commission for its outstanding contributions towards the restoration and protection of the waterways of Ohio's Great Lake.

Recognizing that land use and stream stewardship are better directed at the local level, the Black River RAP has been dedicating considerable effort toward the development of subwatershed groups. The AOC has been divided into six subwatersheds: the mainstem; French Creek; the West Branch; Plum Creek; the northern East Branch; and the Southern East Branch. Various studies and projects have been initiated in all these subwatersheds.

In 2003, funded by a grant from U.S.EPA on behalf of the Lake Erie Public Forum, the Lorain County Community Development Department was able to hire a local watershed coordinator. The primary role of the coordinator was to initiate development of a watershed plan on the West Branch, a tributary highly impacted by agricultural runoff. A local advisory board was established and draft watershed plan prepared. Several workshops have been held to provide instruction on the proper application of atrazine and options to reduce its use. Under subsequent grants from U.S.EPA and the Ohio Coastal Management Program, the local watershed coordinator's role expanded to also include French Creek, Plum Creek and northern East Branch tributaries.

Using simplistic testing for *E. coli*, monitoring has been initiated to determine the more polluted areas in the watershed and the sources. Efforts have also begun to get the members of the watershed groups involved in collecting water quality data from the streams.

Next Steps

- Working with the Lorain County Community Development Department watershed coordinator, the RAP is creating a watershed group for French Creek and continuing planning for the West Branch.
- A TMDL is underway for the Black River and will further define limits for identified contaminants of concern.
- The Black River RAP has adopted the Delisting Targets for Ohio Areas of Concern (Ohio EPA, 2005) and will be reassessing BUIs for each subwatershed based on these targets.
- Use of "sediment sticks" by volunteer monitors is planned to test the concentrations of suspended sediments (as a measure of turbidity) and determine the areas contributing the largest sediment loads. In association with the sediment stick monitoring, Ohio EPA will conduct biological monitoring along the West Branch to calculate fish IBIs and test the correlation between turbidity and the quality of the fish community.
- The Black River AOC continues to experience impacts from sediment loads, bacteria and nutrients. Properly managing urban, suburban and rural land use practices throughout the AOC, including the enhancement and protection of the riparian corridors and wetlands, will improve the quality and productivity of the Black River. The Black River Watershed Initiative and the Black River RAP will continue to coordinate on the organization and implementation of monitoring and remedial actions needed to restore the entire Black River watershed.

Maumee River RAP, Ohio
www.maumeerap.org

History

The Maumee RAP process began in 1987, coincidently as the IJC unveiled the 1987 version of the Great Lakes Water Quality Agreement at their biennial meeting in Toledo. The Stage 1 Report was written by the diverse membership of the Water Quality Subcommittee under the Toledo Metropolitan Area Council of Governments, with oversight by Ohio EPA. The boundaries of the AOC include the mainstem of the Maumee River from RM 22.8 to Maumee Bay, Duck Creek, Otter Creek, Cedar Creek, Grassy Creek, Crane Creek, Swan Creek, and the Ottawa River. In 1992, the AOC was expanded to include Packer Creek, Turtle Creek, Rusha Creek and the Toussaint River, all east of the Maumee mainstem and direct tributaries to Lake Erie. The 1990 Stage 1 Report identified 10 beneficial use impairments including: restrictions on fish and wildlife consumption; degraded fish and wildlife populations; fish tumors or other deformities; degradation of benthos; restrictions on dredging; restrictions on drinking water; eutrophication; beach closings; degradation of aesthetics; and loss of fish and wildlife habitat.

The Maumee RAP Committee makes formal decisions for the organization and oversees eight action groups. The action groups are classified as issue, support or watershed-specific. The RAP continues a very active public outreach and education program. They have held workshops covering such topics as: agricultural runoff and best management practices; urban storm water runoff; pollution prevention; drinking water and pesticides; watershed planning; environmental risk, etc. A Recommendations for Implementation Report was completed in 1991. A 10-year Activities and Accomplishments Report was completed in 2002 and set the stage for identifying next steps toward restoration. Much work has been done on the Ottawa River, the most contaminated part of the Maumee AOC. Remedial actions at the Dura, Stickney, Tyler and King Road landfills have reduced significant loads of PCBs to the Ottawa River. Soil and sediment remediation at the Texileather and Fraleigh Creek sites removed more than 57,000 lbs of PCBs from the river. Extensive additional work has been done to further characterize contaminated sediment levels and locations, assess environmental and human health risk, and prioritize river segments for clean up. An award winning documentary entitled: Fate of a River Revisited was broadcast on PBS and continues to be shown to local groups.

Progress since 2004 LaMP Report

An intensive multi-media public education campaign, entitled "Give Water a Hand", was recently completed. Its aim was to address some of the requirements for Phase 2 Storm water regulations and alert folks to the importance of water conservation, septic system maintenance and storm water management. The success of this program led to the initiation of a similar campaign to be focused on small business.

The Maumee RAP undertook an intensive and ambitious effort to create the Maumee AOC Stage 2 Watershed Restoration Plan. This plan combines the IJC requirements of a Stage 2, U.S. EPA and Ohio requirements for a watershed action plan, attention to the non-point source management measures of the Ohio Coastal Management Plan, and consideration of TMDL and natural resource damage investigations in the AOC. The plan underwent public review in November 2005 was submitted to Ohio EPA, U.S. EPA and the IJC for review in early 2006.

A GIS based wetlands inventory of Lucas County was completed for use in identifying wetlands for protection and as mitigation sites. Projects for restoring wetlands in both Duck and Otter Creek watersheds are underway.

A grant was received from U.S. EPA/GLNPO to conduct the first phase of an ecological and human health risk assessment for Duck and Otter Creeks.

A Longterm Control Plan (LTCP) to address Toledo bypasses and CSOs was approved.

Next Steps

- The Stage 2 Watershed Restoration Plan provides a comprehensive list of actions needed to restore the AOC. Once this plan is approved by Ohio EPA/U.S. EPA/IJC, local organizations agencies need to buy in to the plan and implement the components applicable to their mission and authorities.
- Funding is needed to complete Phase 2 of the risk assessment for Duck and Otter Creeks to determine the need for sediment remediation.
- An application was submitted to conduct sediment remediation on the Ottawa River under the Great Lakes Legacy Act (GLLA). Initial GLLA review required additional sampling to better describe the project components. Sampling was done by GLNPO in 2005 and results are being analyzed for next steps.
- Field data for much of the AOC has become dated. The RAP petitioned Ohio EPA to accelerate the TMDL schedule for Swan Creek, Duck Creek and several smaller tributaries near the mouth of the Maumee River. The request was approved and field sampling will be done in 2006. This information will allow the RAP to reassess the beneficial use impairments in these segments and help prioritize remedial actions needed. A TMDL for the Toussaint River is underway.
- Dam removal and stream restoration is planned for the mid Ottawa River. Contact and fish consumption advisories in the area will be reviewed to determine if they are still relevant.
- A larger watershed plan development project has been initiated for the entire Maumee River basin under a congressional line item request to the USACE and NRCS. The RAP will be involved to connect their efforts with the new ones to work toward the goal of improving the ultimate discharge of the river to Maumee Bay and the western basin.

River Raisin RAP, Michigan

www.riverraisin.org
www.epa.gov/glnpo/aoc/rvraisin.html
www.riverraisin.org/raisin_projects/river_raisin_area_of_concern.html

History

Located in Monroe County, Michigan, the AOC includes the lower 2.6 miles of the River Raisin from the low head dam (#6) and extends half a mile out into Lake Erie. It also includes the nearshore zone of Lake Erie north and south of the river mouth. The River Raisin AOC has nine beneficial use impairments including: fish and wildlife consumption advisories; degraded fish and wildlife populations; bird or animal deformities or reproductive problems; degraded benthos; dredging restrictions; eutrophication; beach closings; degradation of aesthetics; and loss of fish and wildlife habitat. The impairments are primarily due to historical discharges of oil and grease, heavy metals, and polychlorinated biphenyls (PCBs) from industrial facilities that have contaminated sediments in the river. In addition, industrial and municipal waste discharges and changes in water flow have historically caused problems with eutrophication and high levels of *E. coli*.

Progress since 2004 LaMP Report

Automotive Components Holdings, LLC (ACH) and the U.S. Fish and Wildlife Service entered into a cooperative management agreement in 2005 to incorporate 240 acres of coastal wetlands, called Eagle Island Marsh, into the Detroit River International Wildlife Refuge. The Eagle Island Marsh is located behind the ACH plant and is bordered by the Sterling State Park to the north, Lake Erie to the east, and the River Raisin to the south. This large wetland complex is unique to the region and contains marshland, transitional meadows and forested wetlands. Eagle Island Marsh supports significant beds of the threatened American Lotus, a pale yellow flower that is the nation's largest aquatic wildflower and the official clean water symbol of the State of Michigan.

The City of Monroe was awarded an MDEQ Coastal Management Program grant in 2004 to conduct a field assessment of all open waterways within the city. This comprehensive assessment will identify BUIs, identify best management practices to address the BUIs, and will provide a means to implement natural resource conservation programs to restore the BUIs.

In 2004, the MDEQ nominated the River Raisin AOC for project funding consideration under the Great Lakes Legacy Act. The nomination is currently pending action by the U.S.EPA Superfund program.

The MDEQ and U.S.EPA-GLNPO conducted pre- and post-navigational dredging surveys for PCBs in 2003 and 2004. Sampling included volatile organics, metals, PCBs, oil and grease, whole sediment bioaccumulation tests, caged fish, and edible portion fish tissue sampling. PCBs from the turning basin downstream were identified as the main contamination "hot spot". The studies indicated that there is significant potential for uptake of PCBs into the food web. An addendum was completed for the remedial alternatives evaluation report, recommending dredging of contaminated sites, particularly the turning basin, in the AOC.

The River Raisin Watershed Council was awarded $12,800 in grant funds in 2003 to conduct a benthic macroinvertebrate community and stream habitat assessment in the River Raisin Watershed.

Next Steps:

- The Public Advisory Council will be working with the MDEQ in the upcoming year to integrate locally-derived goals and restoration targets with the statewide restoration criteria.

Rouge River Area of Concern, Michigan

www.rougeriver.com

History

The Rouge River watershed is an urban/suburban watershed of 48 communities that drains 466 square miles of southeastern Michigan and discharges into the Detroit River. It is the oldest, most heavily populated and industrialized area in southeast Michigan. The river has four main branches totaling 125 miles of waterways, includes 400 lakes and ponds, and provides recreational opportunities for more than 1.5 million people. The AOC includes the entire watershed.

The Rouge River AOC has nine beneficial use impairments. These include: restrictions on fish and wildlife consumption; degraded fish and wildlife populations; fish tumors or other deformities; degraded benthos; dredging restrictions; eutrophication; beach closings; degraded aesthetics; and loss of fish and wildlife habitat. The Rouge River suffers from typical urban watershed stressors including discharges from combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), non-point sources, limited industrial discharges, contaminated sediments and high flow variability. These factors have resulted in public health advisories for fish consumption and water recreation, poor biotic communities, impoundment eutrophication, and damage to the stream channel morphology.

Progress since 2004 LaMP Report

The Rouge River Watershed Local Management Assembly is a voluntary organization of 38 local municipal governments and three counties located in part or totally within the Rouge River watershed. The Assembly worked to get passage of the Watershed Alliance legislation, Act No. 517, on January 3, 2005. This legislation authorizes the organization to function as a legal inter-governmental entity capable of seeking grants and other sources of outside funding to implement watershed management plans. The Assembly is now in the process of transitioning into a new organization called the Alliance of Rouge Communities (ARC) in an effort to meet the requirements of the Watershed Alliance law.

In October 2005, the Rouge River Remedial Action Plan Advisory Council (RRAC) released the Rouge River Report Card, which is a reader-friendly summary of the status of BUIs in the Rouge River AOC.

In 2004, the Rouge River Remedial Action Plan was updated and revised. The plan defined an ambitious 20-year program of actions needed to realize the vision of: "A Rouge River Watershed that is aesthetically pleasing, clean and safe, that supports a healthy, diverse fish and wildlife community, and that provides an enriching variety of recreational experiences." The document also identified six BUIs that might be ready for removal/delisting.

Continued monitoring has shown improved water quality. Dissolved oxygen levels are higher at most monitoring stations compared to five years ago, and bacteria counts are declining. There have been numerous habitat restoration and streambank stabilization projects conducted throughout the Rouge River watershed.

All 10 Combined Sewer Overflow (CSO) retention/treatment basins planned under Phase 1 of the Rouge watershed CSO control program continue to operate and are removing a significant source of untreated sewage overflow to the Rouge River. A total of 77 of the 83 Phase 1 CSO outfalls are now under control (basins) or have been eliminated by sewer separation. The West Dearborn CSO control program Phase A project is under construction. The City of Detroit Upper Rouge Tunnel is under design.

Thirty-six new grant-funded community projects were awarded in 2004, of which 32 projects have been completed and are consistent with the seven Rouge Subwatershed Management Plans.

Next Steps

- In 2005, Friends of the Rouge River received a U.S.EPA-GLNPO grant to develop a comprehensive GIS database of critical habitat areas. The GIS database will be used as a tool to set measurable restoration and delisting goals for fish and wildlife habitat BUIs identified in the Rouge River AOC.
- The Friends of the Rouge River received a Michigan DEQ volunteer monitoring grant in 2004 to continue its Rouge River benthic monitoring and frog and toad survey programs. This work is ongoing.

Detroit River RAP (Bi-national)

History

The Detroit River is a 51 km (32 m) connecting channel between Lake St. Clair and Lake Erie. The bi-national AOC includes the Detroit River and its watersheds, covering an area of over 2000 km^2. Over 75% of the total land area is in Michigan. The Canadian portion of the AOC is approximately 60,000 hectares and includes virtually all of the municipalities of Windsor and LaSalle, and parts of Amherstburg, Tecumseh, Kingsville and Essex. Some 100 communities rely on the river for drinking water with most of the population concentrated in the cities of Detroit, MI and Windsor, ON.

In the original Stage One RAP, only eight of the 14 BUIs were thought to be impacted. However, additional research has now demonstrated that 11 of the 14 BUIs are likely impaired. The impairments are a result of a number of factors, including historical industrial activity, agricultural practices, and urban development in the watershed. Major sources of impairment to the bi-national AOC are from CSOs, sanitary sewer overflows, municipal and industrial discharges, storm water runoff, and loss of habitat for fish and wildlife. Due to high volumes of water entering the river, upstream sources contribute considerable contaminant loads. The river is the single largest source of contaminants to Lake Erie.

Distinct RAP implementation frameworks have been developed for the Canadian and Michigan sides of the AOC, under the guidance of the 1998 Four Agency Letter of Commitment signed by Environment Canada, U.S. EPA, Ontario Ministry of the Environment, and Michigan Department of Environmental Quality. The Detroit River RAP Team guides the U.S. implementation. The Detroit River Canadian Cleanup (DRCC) process guides Canadian implementation efforts. The DRCC is organized into: the Detroit River Canadian Steering Committee comprised of senior managers; the Detroit River Canadian Implementation Committee comprised of technical Agency representatives; Detroit River Canadian Public Advisory Committee; and the Detroit River Outreach and Communication Committee.

Jointly, the Detroit River RAP Team and the DRCC are working toward fostering actions that will improve the conditions of impaired beneficial uses.

U.S. (Michigan)

www.detroitriver.org

Progress since 2004 LaMP Report

In 2005, Friends of Detroit River (FDR) agreed to take the lead role as coordinator of the U.S. Detroit River Public Advisory Council. FDR has reconvened the Public Advisory Council (PAC) to engage the community in the restoration of the AOC.

In 2004 the Detroit River AOC was chosen as the first Great Lakes Legacy Act site for the dredging of Black Lagoon contaminated sediments. Removal of Black Lagoon contaminated sediments was a key remedial action identified in the 1996 RAP. The project dredged 115,600 cubic yards of contaminated sediments, and was completed in September 2005.

Next Steps

- The U.S. Detroit River Public Advisory Council plans to focus its activities towards adopting bi-national delisting criteria and a Stage 2 RAP report beginning in 2006.
- U.S. EPA awarded a grant in 2005 to MDEQ for a project to identify non-point and non-traditional pollutants in the Detroit River AOC. Work on the project will be completed in 2006-2007.

Canada (Ontario)

www.detroitriver.ca

Progress since 2004 LaMP Report

The Detroit River Canadian Cleanup (DRCC) continues to be the local RAP coordinating body on the Canadian side. DRCC activities are supported by an Implementation Specialist (funded jointly by the federal and provincial governments) who organizes DRCC activities and serves as a point person for the Canadian RAP. Early in 2005, the DRCC developed a master five-year work plan, including activities of all committees. Activities are prioritized on an annual basis, which allows for the adaptation of the plan to changing needs and conditions.

In 2005, the DRCC finalized delisting criteria for the Canadian portion of the Detroit River RAP. A public-friendly report outlining the criteria was prepared to educate the public about the RAP process. There is acknowledgment that there may need to be future modifications to these criteria, and that there is still a need for bi-national criteria, but the passage of these interim targets was an exciting event.

One of the key focuses of the DRCC recently has been on research and monitoring. In 2004, the DRCC was one of the conveners of the State of the Strait Conference, with a focus on “monitoring for sound management”. The Great Lakes Institute for Environmental Research has continued its focus on the Detroit River with sediment sampling work over the past several years. The sampling includes areas all along the corridor, which allows for a big-picture view of sediment issues in the corridor ecosystem.

A DRCC Monitoring and Research Work Group was formed in 2004, and has developed a Monitoring Framework Plan for the river. The Plan sets ambitious goals for ongoing whole-river monitoring activities in the river and corridor. Part of the role of this Work Group is to update the status of the BUIs in the river and that task has already been initiated. An update of the status based on existing information is expected to be completed by mid-2006, while a comprehensive assessment of BUI status is anticipated for December 2007.

Another specific area of research being pursued is contamination in the Turkey Creek watershed. Research has demonstrated elevated contaminant levels in both Turkey Creek and Little River, and a multi-stakeholder group is working to track down the source of the problem. This effort is supported by a 2005 background investigation report into these watercourses that brought together all existing information and research.

Utilizing funding from Environment Canada, the Essex Region Conservation Authority (ERCA) has completed surface water quality monitoring for conventional pollutants at 18 sites around the AOC.

Another major RAP focus is the improvement of fish and wildlife habitat. The Habitat Work Group has made a substantial start on developing a prioritized aquatic habitat management plan for the river. This is a positive addition to the ongoing RAP focus on terrestrial and riparian areas. Large-scale habitat restoration projects have been completed in the watershed every year by the ERCA and the Essex County Stewardship Network, and increasingly, these projects are including wetland and fish habitat components. Other smaller-scale habitat restoration projects are undertaken by public watershed groups on a semi-annual basis, and include some large, ongoing projects such as the 'cloverleaf' naturalization project in the Little River watershed. Efforts to improve habitat for bald eagles have also been a focus of activity. An existing nesting site on Peche Island has been supported by the erection of platforms that are more stable than the existing nesting tree. The project also involves efforts to track eaglets once they leave the nest to learn about their movements and efforts to raise public awareness about the need for quality habitat in the Detroit River watershed to support key sentinel species like bald eagles.

Seventy-seven agricultural BMP projects including the installation of buffer strips, rock chutes, tree plantings and septic system upgrades have been completed through ERCA's NPS grant program, utilizing funding from Environment Canada. In 2004, over 900 ft. of shoreline was enhanced using soft engineering techniques at Parks Canada's Fort Malden National Historic Site.

A number of efforts have been made to reach out to the public to provide education about the RAP process, to involve them in the process, and to encourage them to seek commitment to the RAP from government officials. A number of public workshops have been held, including ones focused on research and habitat. A new display was purchased in 2004 to provide updated information, and an extended newsletter was published in 2005. This newsletter is in addition to other publications focused on specific topics such as naturalization and water conservation. Efforts by the Public Advisory Council to bring more members of the general public into the process are ongoing.

In 2004, a very successful Household Mercury Collection was held, which brought in over 220 pounds of mercury during a one-month period. That project was followed up by the publication and distribution of a fact sheet about fluorescent light bulbs and steps that businesses should take to dispose of them. Another phase of the project is planned for early 2006, where pharmaceuticals as well as household mercury items will be collected.

Many organizational members of the DRCC continue to undertake remedial actions within their own organizations, frequently seeking the endorsement or support of the DRCC for the projects. These projects include sewage treatment plant upgrades (Lou Romano Plant upgrade expected to be completed in 2006, Amherstburg environment assessment of the upgrade is nearly complete), habitat restoration, non-point source pollution prevention, scientific research, and combined sewer overflow management.

Next Steps

- The development of true bi-national delisting criteria is a priority, and should aid in moving the remediation process along.
- Another much-anticipated development is the planned completion of the BUI status updates in 2006 and 2007.
- Funding renewal for the Implementation Specialist position will be required in 2006, and is critical to the ongoing success of the RAP.
- Other Canadian RAP activities that are ongoing are the implementation of the Monitoring and Research Plan, finalization of an Aquatic Habitat Management Plan, and ongoing work with municipalities to protect habitat and reduce municipal loadings. An ongoing focus on habitat restoration and rural NPS projects is needed to achieve natural areas cover and tributary water quality targets.
- The Public Advisory Council is preparing a series of report cards addressing BUIs, beginning with #1 (fish consumption advisories) in 2006, and is also looking forward to increased involvement with the new US PAC.
- A household hazardous waste collection will be held in 2006 to include both mercury and pharmaceuticals.

Clinton River RAP, Michigan
www.crwc.org/rap/raphome.html

History

Located just north of Detroit and flowing 80 miles from its headwaters into Lake St. Clair near the city of Mount Clemens, the Clinton River drains 1,968 km^2 (760 square miles) of southeastern Michigan, including portions of Oakland and Macomb Counties and small areas of St. Clair and Lapeer Counties. The AOC includes the entire Clinton River watershed, as well as a portion of Lake St. Clair immediately downstream of the mouth of the Clinton River. There are eight beneficial use impairments in the Clinton River AOC including: fish and wildlife consumption advisories; degraded fish and wildlife populations; degraded benthos; dredging restrictions; eutrophication; beach closings; degradation of aesthetics; and loss of fish and wildlife habitat.

Although historical industrial and municipal discharges were the primary causes of environmental degradation in the Clinton River, ongoing contamination problems are almost exclusively of non-point source origin. Land use in the watershed is predominantly commercial and residential, although agriculture is still common in the North Branch subwatershed. The main industries in the area are automotive-related. Stormwater runoff, including the two municipal systems still experiencing combined sewer overflows, is the greatest source of water quality degradation.

Clinton River priorities include elimination of combined sewer overflows and separate sanitary overflows, non-point source pollution control, superfund waste site remediation, spill notification, habitat restoration, and elimination of illicit sewer connections and failing septic systems.

Progress since 2004 LaMP Report

The Public Advisory Council (PAC) received a grant from the Great Lakes Commission to develop delisting criteria for six of the Clinton River AOC beneficial use impairments (BUIs) in 2004-2005. A technical committee of the PAC has been working with consultants over the past year to develop locally-derived delisting criteria that are consistent with Michigan Department of Environmental Quality's Guidance for Delisting Michigan's Great Lakes Areas of Concern.

Oakland University received a grant to conduct an assessment of contaminated sediments in 2003-2005.

The Clinton River Watershed Council launched a major stormwater education effort in 2004.

The Clinton River Watershed Council launched the Adopt-A-Stream volunteer river monitoring program in spring 2005. More than 150 volunteers were recruited to monitor two dozen sites in the first year of the program.

Seven subwatershed planning groups consisting of more than 50 communities and county agencies have formed since 2001, and are currently developing subwatershed management plans and Storm Water Pollution Prevention Initiatives as part of the requirements of the National Pollutant Discharge Elimination System (NPDES) Phase II stormwater permit.

Next Steps

- The Clinton River PAC received a grant from U.S. EPA-GLNPO in 2005 to build on their work in setting restoration/delisting targets for their BUIs. The project is just underway, and will result in the development of delisting targets for fish and wildlife populations, habitat, and benthic community BUIs, and will update the RAP to reflect those targets.
- All 42 municipalities that must comply with the NPDES Phase II stormwater permit decided to apply for Michigan's watershed-based permit, and have thus formed subwatershed planning groups that meet monthly to work on watershed planning and stormwater management initiatives.
- The Macomb County Health Department is currently working to identify and remediate bacterial sources throughout the watershed, and a number of communities are actively working on upgrading the wastewater treatment system.

- The Clinton River Watershed Council will continue to coordinate major public education and outreach events, including River Day and Clinton Clean-Up, in collaboration with many local governments and community organizations.

St. Clair River RAP (U.S. and Canada)

www.friendsofstclair.ca/rap/

History

The St. Clair River flows southward about 40 miles (64 km) connecting the southern tip of Lake Huron to Lake St. Clair. The river is part of the boundary between the United States and Canada. The St. Clair River branches into several channels near its mouth at Lake St. Clair, creating a broad delta region. The AOC includes these important wetlands from St. Johns Marsh on the west (near Anchor Bay, Michigan) to the north shore of Mitchell's Bay in Ontario. Agriculture is the predominant land use within the river's watershed, but intensive industrial development has occurred in and near the cities of Port Huron and Sarnia.

The St. Clair River AOC has ten beneficial use impairments (BUI): restrictions on fish consumption; fish tainting; bird and animal deformities; degraded benthos; restrictions on dredging; restrictions on drinking water consumption and taste and odor problems; beach closings; degradation of aesthetics; added cost to agriculture and industry; and loss of fish and wildlife habitat. The impairments are primarily due to intensive agriculture and industrial development in and near the cities of Port Huron and Sarnia. The heaviest concentration of industry (including a large petrochemical complex) lies along the Ontario shore near Sarnia. Several communities along the St. Clair rely on the river as their primary source of drinking water. Industries, including petroleum refineries, chemical manufacturers, paper mills, salt producers and electric power plants, need high quality water for their operations as well. Ships carrying cargo between the upper and lower Great Lakes ply the St. Clair River.

St. Clair River RAP priorities include contaminated sediment remediation on the Canadian side of the river, elimination of combined sewer overflows and sanitary sewer overflows on both sides of the river, elimination of spills to the river from sources downstream of Sarnia, Ontario, and ensuring proper notification when spills do occur.

Progress since 2004 LaMP Report

A total of 13,370 m^3 of mercury-contaminated sediment were removed from offshore of Dow Chemical Canada Inc.

A St. Clair RAP Progress report was completed in 2005. The report highlighted remedial actions that have been completed the last four years, and evaluated the status of the 10 BUIs in the St. Clair River AOC.

In the fall of 2005, a St. Clair River RAP Canadian Implementation Committee was re-established to guide implementation of the remaining remedial actions on the Canadian side of the AOC. Actions on the U.S. side of the AOC are coordinated by the U.S.EPA and Michigan DEQ, who also informally participate on the Canadian committee as needed.

In 2005, wetlands were created on the ICI Phosphate site near Corruna, ON in order to treat wastewater prior to discharging into the St. Clair River. Work undertaken on this site is a part of the long term site restoration plan.

In 2005, a 50-acre naturalization project on Terra Industries property directly adjacent to the St. Clair River south of Sarnia was completed that included planting and restoration of trees and shrubs, tall grass prairie and wetlands. Terra Industries Inc. (which is a nitrogen-producing facility) provided the land, and the work was carried out by the St. Clair Region Conservation Authority, Rural Lambton Stewardship Network and Ducks Unlimited Canada.

Next Steps

- The current St. Clair River AOC delisting criteria are not specific enough to determine restoration success for all of the BUIs. In 2006, the Canadian Implementation Committee, Michigan DEQ, and the U.S.EPA in consultation with the Bi-national Public Advisory Council (BPAC), will begin to refine the delisting criteria based on current U.S. and Canadian federal and state/provincial guidance and standards.

- The BPAC plans to develop a brief "Report Card" public outreach tool that would highlight the issues in the AOCs, track restoration progress, and engage the local communities in the efforts to restore the AOC.
- In May 2005, Macomb and St. Clair Counties received a $1 million federal earmark to establish water quality monitoring for the St. Clair River and Lake St. Clair. A work plan for the project is currently being negotiated between U.S.EPA and contractors for Macomb and St. Clair Counties.
- Additional contaminant monitoring and effects studies are planned that will assess the status of the degradation to benthos, fish consumption advisories and bird and animal deformities BUIs.
- A facilitated workshop will be held in early 2006 to comprehensively assess habitat gains and losses in the AOC, identify potential for aquatic restoration and review the delisting criteria.

Wheatley Harbour RAP, Ontario

www.on.ec.gc.ca/water/raps/wheatley/intro_e.html

History

Wheatley Harbour is a small, confined harbour on the north shore of Lake Erie. It is the busiest commercial fishing harbour in Ontario, the centre of the province's commercial fish processing industry, an access point for Lake Erie sport fishing, and supports a commercial baitfish fishery. It was originally listed as an AOC because of dissolved oxygen depletion, elevated bacterial levels, nutrient enrichment, and PCB contamination of sediments. The AOC encompasses the harbour proper and the wetlands in lower Muddy Creek, a small tributary that flows into the AOC from the north.

A combined Stage 1/Stage 2 report was completed in 1998. The report highlighted five environmental concerns – contaminants in sediments, high phosphorus concentrations, poor water clarity, bacterial contamination, and habitat loss – that result in the following beneficial use impairments: restrictions on fish consumption; restrictions on dredging activities; eutrophication or undesirable algae; loss of fish and wildlife habitat; and degradation of fish and wildlife populations (not solely attributed to factors in the AOC).

A progress report updating the status of the AOC was completed in November 2002.

Progress since 2004 LaMP Report

The following activities have been undertaken in the AOC since the 2004 LaMP update report:

RAP Management and Coordination

- The Wheatley Harbour Implementation Team (WHIT) was formed in January 2004, with representation from Environment Canada, Ontario Ministry of the Environment, Ontario Ministry of Natural Resources, Ontario Ministry of Agriculture and Food, Essex Region Conservation Authority, and the Essex County Stewardship Network.
- A comprehensive work plan for 2005-2007 was produced in June 2005 that outlines the activities to be pursued in order to complete all actions toward delisting of the AOC.
- A review of the RAP delisting criteria was initiated in fall 2004.
- A draft RAP update report for the time period 2001-2003 was completed in June 2004.

Workshops and Outreach

- A two-day State of Wheatley Harbour Workshop was held in April 2005. The workshop brought together federal and provincial government management, research and implementation staff to review the most current information on the environmental conditions of the AOC. The meeting provided a forum for discussion about information gaps and needs and future directions.
- Public outreach was re-initiated via a meeting with the Southwest Outdoors Club, a new, 200-member hunting and fishing club based out of Wheatley.

Monitoring, Research and Implementation

- A total of 40 non-point source projects were conducted within the Muddy Creek watershed. These projects, including 23 septic system upgrades, eight tree plantings, seven buffer strips, and two soil erosion protection projects, resulted in improvements in the quality of water entering the AOC.
- A total of five habitat restoration projects were conducted in the AOC-proper, resulting in 6.4 hectares of habitat restored.
- Wetland sediment and concurrent young-of-year fish sampling were conducted in December 2004. The data were used to develop a contaminants pathway model in June 2005.
- Historical dredge disposal sites on the east and west sides of the wetland were sampled in August 2004 and laboratory analyses for PCBs conducted and finalized in March 2005.
- Electromagnetic testing was conducted in spring 2005 to follow up on anecdotal information concerning electrical transformers buried on the east side of the wetland.
- All outfalls draining into the harbour were located and mapped in September 2005 and sampled for PCB analysis in November 2005.
- Fish and snapping turtle health effects results (based on 2001 and 2002 sampling) were completed in March 2005.
- A study of wetland hydrology (water flow) and sediment transport (re-suspension) and of the two PCB hotspots was initiated in September 2005.

Next Steps

- PCB track-down activities will be completed, including sediment sampling of historic dredge disposal sites, water sampling at outfalls, and core sampling at wetland PCB hotspots. The purpose of this work is to determine whether active sources of PCBs remain in the AOC. The sediment core sampling will be used to estimate the volume of contaminated sediment and will inform the development of a sediment remediation plan.
- Further non-point source and habitat restoration work upstream of the AOC will be done to continue to improve the quality of water entering the AOC from the upstream areas.
- The hydrology/sediment study that was initiated in September 2005 will be continued. This work will lead to a better understanding of water, sediment and contaminant flow within the Muddy Creek wetland and, combined with the results of the track-down activities, will allow an understanding of why PCB levels in the wetland sediments have not really declined over the last 20 years.

9.3 Watershed Projects

Erie and Cattaraugus County Watershed Projects, New York

History

The Erie County Soil and Water Conservation District develops and implements a wide range of projects addressing habitat, streambank stabilization, erosion control, nutrient management, agricultural environmental management planning, non-point source, stewardship, and forest/community management. Other projects by environmental and governmental organizations address land use, urban sprawl, large animal farms, stormwater, construction, conservation incentives, water quality, and public access.

Progress since LaMP 2004 Report

A number of land, stream, and, watershed restoration and protection projects are ongoing and planned in these counties.

Next Steps

- In Cattaraugus County, a watershed protection project has been funded for Cattaraugus Creek that has two main components: 1) a technical study of sediment transport and quality in highly erosive areas with a hydrologic model to address loadings; and 2) a community vision development for a stream corridor strategy. Issues to be addressed include land use, urban sprawl, and watershed protection. This funded grant project is led by New York Rivers United of which The Nature Conservancy and Cattaraugus County government agencies are primary partners.

Lake St. Clair Program (Bi-national)

Lake St. Clair, together with the St. Clair River and the Detroit River, provide the connecting channel between Lakes Huron and Erie and forms part of the international boundary between Canada and the United States. Significant tributaries to the lake include the Sydenham and Thames Rivers (Canadian) and the Clinton River (US). The total drainage basin area is 13,500 km^2 with 23% draining U.S. lands and 77% draining Canadian lands.

The need for a Lake St. Clair focus to coordinate and communicate the various on-going programs and to identify areas where work is needed was recognized by the four lead government agencies (Environment Canada, U.S.EPA, Ontario Ministry of Environment and Michigan Department of Environmental Quality) and in 2000 they approved a resolution to include Lake St. Clair under the Four Agency Letter of Commitment. Under this commitment, a framework for managing Lake St. Clair was completed, a bi-national monitoring committee (MUGLCC) established, and two bi-national monitoring activities inventories (MUGLCC 2000 and 2002) have been published.

The key elements that form the basis of the management framework are: a Bi-national Partnership Agreement (Four Agency Letter of Commitment); a Bi-national Management Committee (Four Agency Management Committee); a Bi-national Working Group; separate local U.S. and Canadian Watershed Coordinating Committees; and a Biennial State of Lake St. Clair Conference. A very successful 2005 Lake St. Clair Biennial Conference was held September 21-22 in Wallaceburg, Canada. During the two-day conference, about 150 attendees representing science, all levels of government, non-governmental organizations, and the general public heard from 40 speakers who highlighted environmental monitoring, research, implementation and management actions that have taken place over the last few years. Several themes were explored including: land and water resource uses, environmental monitoring of contaminant sources and trends, human health, fish and wildlife health in the St. Clair watershed, habitat and biodiversity, and physical conditions and processes.

Key stressors that have been identified for the watershed include land use, commercial navigation and recreational navigation. These sources have resulted in increased nutrients and chemicals in water and sediment; increased bacterial levels at beaches; fish consumption advisories; and changes in habitat, fish and wildlife populations, and biodiversity.

U.S.

Progress since 2004 LaMP Report

In 2004, the U.S. National Oceanic and Atmospheric Administration (NOAA) and the Great Lakes Commission completed a two-year cooperative effort culminating in the completion of a Lake St. Clair coastal habitat assessment and integrated coastal management decision support tool (www.glc.org/habitat/icmt.html). The Assessment focuses on Lake St. Clair's coastal environment and brings together recent data and information about the habitats in the 10 mile perimeter surrounding Lake St. Clair. The decision support tool will help users to examine how habitats function, identify and rank landscapes and perform land use scenario testing.

In 2005, the U.S. Army Corps of Engineers released the St. Clair River/Lake St. Clair Comprehensive Management Plan to the public. The Management Plan outlines ten goals for environmental restoration actions needed for Lake St. Clair. These goals are:

- Pollution does not threaten public health and the health of the watershed;
- All biological communities and habitats are healthy, diverse, and self-sustaining;
- Water is safe for drinking;

- Water is safe for swimming;
- Fish and wildlife are safe to consume;
- Land use activities are sustainable and support a healthy watershed;
- Recreation and economic activities impacting the lake are sustainable and support a healthy watershed;
- Data and information are available to ensure informed management decisions;
- All entities responsible for natural resources and environmental protection within the watershed are working together in a collaborative manner to protect and enhance the watershed;
- The public is informed about environmental issues and engaged in activities to restore and protect the lake.

The recommendations in the Management Plan will help to achieve the goals and serve as a basis to guide future US actions and develop priorities for Lake St. Clair. One of the recommendations in the Management Plan was to ensure safe drinking water and, in 2005, Macomb and St. Clair Counties received a $1 million federal earmark for water quality monitoring for the St. Clair River and Lake St. Clair.

Another recommendation in the Management Plan was to "establish a U.S. Lake St. Clair Coordinating Council with representation from federal, state, and local agencies with management responsibilities for the Lake St. Clair watershed to promote and coordinate implementation of the management plan, facilitate communication among stakeholders, establish priorities, monitor progress, and seek funding for management plan activities." In 2005, the local Macomb/St. Clair Inter-County Watershed Management Advisory Group approved a structure that will formally act as the U.S. Lake St. Clair Coordinating Council under the bi-national Four Agency Lake St. Clair management framework. The group will serve as the local US focal point for lake management and provide policy and administrative direction to implement projects and programs within the Lake St. Clair Watershed, using recommendations from the USACE Comprehensive Management Plan as a starting point.

Next Steps

- Macomb County, Michigan, and the U.S. Lake St. Clair Coordinating Council will be developing an implementation strategy to set priorities for more of the recommendations cited in the Management Plan. Macomb and St. Clair Counties, along with the U.S. Lake St. Clair Coordinating Council will develop and implement a drinking water monitoring system for Lake St. Clair and the St. Clair River. The U.S. Coordinating Council will continue their successful efforts to involve relevant Lake St. Clair stakeholders, develop projects, and facilitate funding for future Lake St. Clair actions.

Canada

www.scrca.on.ca/lakestclair.asp

Progress since 2004 LaMP Report

The Lake St. Clair Canadian Watershed Council has released the Lake St. Clair Canadian Watershed Draft Technical Report. The report is an examination of current conditions and identifies management issues. The Council has proposed management recommendations to address the issues identified and has been actively consulting with stakeholders and partners. A final Management Plan including recommendations will be released in 2006.

Next Steps

- The focus for the next two years will be on completing the Management Plan and the corresponding Implementation Strategy.
- Ongoing projects to address non-point sources of pollution, complete a walleye study in the lower Thames River, and continue to develop a corridor-wide hydrology model.

Thames River Watershed, Ontario

www.thamesriver.on.ca
www.lowerthames-conservation.on.ca

History

The Thames River watershed is located in the agricultural heartland of southwestern Ontario. The river is 273 km long and drains a 5,825 km^2 watershed to Lake St. Clair. Flood control reservoirs in the upper portion of the Thames regulate the flow regime of the river. Water quality and aquatic habitat have been altered by land use activities in the watershed. Historical and current land use has resulted in high sediment and nutrient loadings, mainly from non-point sources, and habitat fragmentation and degradation. The Thames contributes the second largest nutrient loadings to Lake Erie, next to the Maumee River in Ohio. The Thames River watershed was identified as a target watershed to implement recommendations from the Lake Erie LaMP. The Upper Thames River Conservation Authority (UTRCA) manages resources in the upper portions of the watershed including London and upstream areas. The Lower Thames Valley Conservation Authority (LTVCA) manages resources in the lower portion from downstream of London to Lake St. Clair. Established in 1947 and 1961, respectively, the UTRCA and LTVCA have well-established watershed management programs. These include flood control, land use and environmental planning, environmental monitoring (surface water, groundwater, fisheries, and species at risk), forestry and agricultural conservation services, community education, and recreation.

Progress since 2004 LaMP Report

Through the Clean Water Program rural landowners receive technical assistance and financial incentives to implement best management practices to reduce rural pollution sources and enhance habitat. In 2004/2005 a total of 204 projects were completed in the Upper Thames watershed.

Hands-on environmental education was provided for 60,000 students since 2004.

An ecosystem-based recovery plan for aquatic species at risk in the Thames River watershed was developed.

Collaboratively with the City of London and a local advisory committee, an updated management plan of the 250 hectare Westminster Ponds/Pond Mills ESA was completed to guide decision-making for the next 10 years.

Ongoing monitoring in the Thames watershed includes surface water chemistry, stream flows, groundwater, fisheries, benthic invertebrate monitoring, and species at risk.

A partnership of agencies (federal, provincial, conservation authorities) and First Nations interested in ecosystem restoration within the Thames River Watershed created the Thames River Ecosystem Restoration Committee in 2003. Current work includes research into walleye survival in the Thames River.

Studies are ongoing with the Ontario Geologic Survey to better define the water bearing zones and to complete a regional groundwater model for Southwestern Ontario.

Work continues to inventory and assess the approximately 225 dams and barriers throughout the watershed and prioritize them for mitigation efforts. Most recently Dingman Creek Weir, located in the City of London, was removed in September 2005 as a result of this work.

Approximately 120,000 trees have been planted for habitat improvement through plantings on private lands and as part of community forestry projects.

Revisions to the Conservation Authorities Act by the Province of Ontario have resulted in a new directive: Ontario Regulation 97/04 – Development, Interference with Wetlands and Alterations to Shorelines and Watercourses. The Generic Regulation will take the place of the Fill, Construction and Alteration to Waterways Regulation by regulating development on defined hazard lands including: erosion hazard lands, flood hazard lands, watercourses, wetlands, other areas of interference surrounding wetlands.

Next Steps

As financial resources become available, the development of an overall watershed plan for the Thames River is a priority. This plan is needed to best direct and target future implementation actions. Many relevant plans are being developed that are key components of a watershed plan. Some of those currently planned or underway include:

- Source Water Protection Plan: an extensive effort led by the Province of Ontario and facilitated on a watershed scale by the Conservation Authorities to protect drinking water.
- Thames River Fisheries Management Plan: develop updated plan to ensure sustainable management of fisheries resources.
- Oxford County Natural Heritage Study.
- 2006 Watershed Report Cards for each of the 28 subwatersheds in the Upper Thames River watershed.
- Continuing to implement stewardship rural non-point source and habitat projects.

Canadian Western Lake Erie Watersheds (including: Hillman, Lebo, Mill, Sturgeon, Big, Fox, Cedar and Wigle Creek watersheds and Point Pelee National Park)

www.erca.org

History

The Canadian portion of western Lake Erie is entirely within the Essex region, located in extreme southwest Ontario, and encompasses all or part of four municipalities including Leamington, Kingsville, Essex and Amherstburg. The region is formerly a glacial lakebed, and is characterized by predominantly clay soils with a very flat topography. Prior to European settlement most of the region was covered in swamp forest, with extensive coastal marshes and some areas of prairie. European settlement has radically altered the landscape, and today just 7.5% of the region exists as natural area (2.5% wetland and 5% forest with very small remnants of prairie). Similarly, water quality has been degraded by human activities, and the region is a significant contributor of nutrients to the lower Great Lakes. Agricultural land uses (primarily cash crops with significant but localized greenhouse, fruit and vegetable production) covers 80% of the region with urban and rural residential dominating the balance.

Due in part to its southernmost location in Canada, the region supports the highest diversity of flora and fauna in the country. It is in the heart of the Carolinian life zone and is also home to approximately 240 federally and provincially listed species at risk. It is a very special place from a natural environment perspective, and also faces significant and unique resource management challenges. The Lake St. Clair-Detroit River- western basin of Lake Erie corridor encompasses the entire region and has been identified as a priority area for LaMP activities.

A diverse suite of programming has been developed by the Essex Region Conservation Authority and its partners in relation to watershed conservation and restoration, hazard lands and flood management, outdoor recreation, and environmental education.

Progress since 2004 LaMP Report

Progress has continued on a number of activities to restore and protect the watersheds draining into western Lake Erie since 2004. Some of these include:

- Clean Water~Green Spaces – for each of the last two years ERCA's municipally appointed Board of Directors has approved this program that sees over $1 million of local levy flow to natural areas acquisition, water quality improvement and habitat restoration programs.
- Protection of Significant Natural Areas through Acquisition –170 acres of significant natural areas were protected through partnership acquisitions in the Cedar Creek watershed.
- A total of 25 water quality improvement projects were completed in 2005, the first year of the Water Quality Improvement Program, through provision of incentive grants to private landowners. Projects include septic system upgrades, buffer strips, rock chutes and other soil erosion control structures, and abandoned wellhead decommissioning.

- ERCA partnered with landowners to restore almost 20 acres of forest and wetland habitat.
- Under the Essex-Erie Aquatic Species at Risk Recovery Strategy, ERCA worked with the Department of Fisheries and Oceans to initiate a recovery strategy process focusing on fish species at risk.
- ERCA maintains 45 surface water quality monitoring stations and eight groundwater monitoring stations and monitors for various parameters, with emphasis on the conventional pollutants. Water chemistry and benthic invertebrate health is monitored.
- Development of a Source Water Protection Plan to prevent contamination of drinking water (primarily surface waters) was initiated in 2005.

Next Steps

- Expansion of ERCA's water quality and habitat restoration programs are a high priority. This requires continued landowner engagement in addition to enhanced funding.
- Prevention of watershed degradation will also be emphasized over the coming period. This will be achieved through the development of Source Water Protection Plans as well as more effective municipal engagement to mitigate land use impacts.

Kettle Creek Watershed Project, Ontario

www.kettlecreekconservation.on.ca

History

The Kettle Creek watershed is located in southwestern Ontario, bordering on the north central shore of Lake Erie. Kettle Creek is a short, deeply incised watercourse that drains 520 km^2 of intensively used agricultural and urbanized lands to Lake Erie at Port Stanley.

Within the watershed valley the bed of the stream is often more than 100 feet below the level of the surrounding lands. Approximately 80% of the watershed is in agricultural use; 15% is forested or marginal land; and 5% is urbanized. The primary agricultural land use is cash crop, and a moderate amount of specialty cropping also exists. Livestock operations are declining in total number of animals, but the animals are more concentrated in a smaller area. Most agricultural lands are systematically tile drained which, along with municipal drains, has reduced wetland features in the watershed landscape by 80% over historical records.

Shoreline erosion monitoring, development controls or prohibitions, flood proofing of new shoreline development, and shoreline protection activities combine along Kettle Creek's Lake Erie shoreline – which represents the fastest eroding shoreline in the Great Lakes (average of two metres recession per year over 100 years) and the largest lake-induced flood damage centre on the Canadian side of Lake Erie.

The population of the watershed is approximately 65,000 people, with a forecast growth of 50% within the next 20 years. A large, as yet unsettled or developed portion of the City of London is located in the northern headwaters of the watershed. As a result of the afore-noted natural features and land uses, the following natural resource management issues exist:

- Flash flooding but otherwise low, and decreasing surface water flows
- Erosion and sedimentation of watercourses and Lake Erie
- Deforestation, and decreasing water and air quality
- Habitat fragmentation and degradation
- Hazard land management in both riverine and lakeshore environments

Kettle Creek's outflow plume into Lake Erie has been identified as a source of sediments laden with nutrients, mercury, and PAH's - all measurable within Lake Erie at 1 kilometre south and 2 kilometres east of the outlet. Both point and non-point sources within the watershed contribute to the Kettle Creek's impact upon Lake Erie.

Progress since 2004 LaMP Report

Progress has continued on a number of activities to restore and protect the Kettle Creek watershed since 2004. Some of these include:

- Habitat Evaluation and Remedial Measures Targeting: Satellite Imaging, Vegetative Cover Assessment, and Benthic (macroinvertebrate) Assessment all combine to target remedial measures for improvement to water quality potential.
- Reforestation: 120,000 trees planted in watershed to buffer watercourses, create interior forest habitat, improve biodiversity, and reduce water and wind erosion and sedimentation.
- Wetland Creation: 20 acre wetland complex developed through private industry partnership. Lands and funds dedicated to Kettle Creek Conservation Authority (KCCA).
- In partnership with the Lake Erie Binational Public Forum, and funded primarily by U.S.EPA, community perceptions of resource management issues and preferred remedial actions combined to form an action-based strategy for the Dodd Creek and Upper Kettle subwatersheds.
- Hands-on environmental education for 1,500 secondary school students.
- Hayden Woodlot and Lake Margaret Management Area master plans completed to guide conservation and protection of key environmental features otherwise subject to threat by adjacent development land uses.
- A comprehensive monitoring system was designed and implementation begun. The system was designed in consultation with Ontario Ministry of the Environment, University of Western Ontario, University of Guelph, Elgin Area Primary Water Board and Grand River Conservation Authority expertise.
- The Ontario Geologic Survey is conducting ongoing studies to better define the water bearing zones and to complete a regional groundwater model and water budget for the Kettle Creek watershed.
- Renewal of KCCA's environmental regulations, watershed-wide.
- Over $175,000 donated to KCCA as registered charity for environmental management and protection works.

Next Steps

- Drinking water source protection goals of the Province of Ontario overlap with environmental protection goals established for Lake Erie LaMP. Characterization of the Kettle Creek watershed, the preparation of a water resources conditions and trends report, the completion of a water budget, and finally the completion of a community based water source protection plan for the watershed will be accomplished over the next two years. Integration with federal programming for Lake Erie, in areas of mutual benefit, is required within the KCCA interface.
- KCCA's environmental monitoring system will be fully designed and implemented. Integrated with completion of all subwatershed community-based conservation strategies, and KCCA's satellite based habitat evaluation tool, an excellent basis for targeting remedial measures for best results will occur. Reporting to the public is a key element of this exercise, to ensure their continued participation.
- The development of a rejuvenated private land stewardship program will occur at the same time.

Long Point and Long Point Bay (including: Big Otter Creek, Big Creek, Lynn River, Nanticoke Creek, Sandusk Creek and Stoney Creek), Ontario

History

Long Point Region Conservation Authority (LPRCA) encompasses a regional watershed area with several third order watercourses draining directly to Lake Erie, both west and east of Long Point and Long Point Bay. Major watersheds include Big Otter in the west, Big Creek, Lynn River, Nanticoke Creek, Sandusk Creek and Stoney Creek in the east. The regional watershed area consists of approximately 2782 km^2, and includes approximately 170 km of Lake Erie shoreline (including the Long Point sand spit). The watershed is largely dominated by two surficial geologic features, namely the Norfolk Sandplain, sweeping down from the north-east through the central and western areas of the watershed, and the Haldimand Clayplain, occupying the eastern 1/3 of the watershed, with occasional bedrock outcrops near the lakeshore and along the shoreline in the east.

The Long Point Region watershed has experienced a number of problems in recent years relating to the impairment of uses of Lake Erie. The Big Otter watershed continues to be a significant source of sediments entering the lake from the north shore, with associated nutrient loadings. Sedimentation and nutrient loadings have impaired fish habitat and wildlife habitats along the major watercourses, especially Big Creek and Lynn River. High bacteria levels in the mid-1990s have persisted on occasion in certain locations. Seasonal low water conditions (both surface water and groundwater) have been significant problems in the past several years. Pathogen problems causing mortality in waterfowl populations along the lakeshore within Long Point Bay flared up seasonally in the early 2000s, but were not of significance in 2004 or 2005.

Progress since 2004 LaMP Report

The LPRCA has had an active land and habitat restoration program in recent years, including 2004 and 2005. Approximately 400 acres of private and public land have been replanted and restored over the past three years, through a cooperative restoration project with Ontario Power Generation and the Long Point World Biosphere Reserve Foundation. Approximately 60 acres of floodplain agricultural land along Big Creek was restored on two properties acquired by the LPRCA. An additional 79-acre parcel of floodplain and wetland area was acquired in 2005, along with 85 acres of upland forest and agricultural land (that will be restored in 2006). A cooperative restoration action plan for the lower Big Creek watershed has been developed in 2005 by a number of partners, including LPRCA. LPRCA is presently working cooperatively with Kettle Creek, Catfish Creek and Grand River Conservation Authorities on water supply source protection planning, at present focusing on watershed characterization and risk assessment.

Next Steps

- The LPRCA will focus attention on the Big Otter and lower Big Creek watersheds in particular, with additional targeted properties for acquisition and/or restoration.
- "State of the watershed" reports are needed for these two watersheds in particular. Surface water and groundwater monitoring programs will need to be made a higher priority in the next couple of years.
- Private landowner extension and stewardship efforts will be a high priority in identified subwatersheds suffering erosion and sedimentation problems, utilizing new funding as available from provincial and federal programs.

Southern Grand River Ecosystem Rehabilitation Initiative, Ontario
www.grandriver.org

History

The Grand River is the largest tributary in the Canadian portion of the Lake Erie basin, draining an area of almost 7,000 km^2. Due to its size and the wide diversity of aquatic habitats it offers, the Grand River is critically important to the health of the Lake Erie ecosystem and to achieving the Lake Erie LaMP restoration goals in the eastern basin of Lake Erie. It has, therefore, been identified in the Lake Erie LaMP as a priority watershed for implementation.

Through the years, many ecological improvements have been realized in the upstream reaches of the Grand River, while water quality, habitat, and fish and wildlife populations in the lower reaches have remained impaired. The Southern Grand River Ecosystem Rehabilitation Initiative is a partnership of agencies with the common objective of restoring the aquatic ecosystem of the lower (southern) Grand River. The initiative commenced in August 2001 with a workshop entitled "Restoration of Healthy Ecosystem Function in the Lower Grand River", which provided a forum for sharing current information on the status of the southern Grand River.

A Working Group, with representation from Environment Canada, Grand River Conservation Authority, Ontario Ministry of the Environment, Ontario Ministry of Natural Resources, Six Nations First Nation, and Fisheries and Oceans Canada, was subsequently formed to coordinate research, monitoring, and implementation efforts in the southern Grand River. Projects undertaken through 2003 included: assessment of the fish community of the lower Grand River and the nearshore areas of Lake Erie, monitoring of fish passage at the Dunnville Dam fishway, initiation of a walleye radio-telemetry study to investigate habitat use and fishway passage by migrating walleye, water quality and benthic community sampling, and an examination of the Grand River plume and its influence on the nearshore areas of the eastern basin of Lake Erie.

Progress since 2004 LaMP Report

A number of projects continued in 2004 and 2005, including walleye radio-telemetry, water quality and benthic sampling, and fish passage monitoring.

A major restoration project was undertaken on Mill Creek, one of the few remaining cold water streams in the lower reaches of the Grand River. Activities included: removal of a dam and the reservoir it created; re-naturalization of the stream channel; riparian tree planting; and cattle fencing. The work has been guided by a community-developed concept for the future of the property.

Next Steps

- A State of the Southern Grand River report is currently being prepared by the Southern Grand River Ecosystem Rehabilitation Working Group. The report will summarize the current status of the southern Grand River ecosystem, identify the main issues facing the southern Grand River, and identify next steps for addressing those issues. This will be followed by the development of an Implementation Plan that will identify priorities and guide on-the-ground restoration activities, and a Research and Monitoring Plan that will identify information needs and guide research and monitoring activities to support the implementation plan and to allow for the tracking of progress.

Table 9.1: Summary of Lake Erie Remedial Action Plan and Watershed Implementation Programs

AOC / Watershed Name	Geographic Area	Stressors	Beneficial Use Impairments/ Management Issues	Restoration Activities Completed (2004 & 2005)	Restoration Activities Needed	Challenges	Next Steps
AREAS OF CONCERN							
Buffalo River	Lower 6.2 miles of river	Sediments, CSOs, past industrial practices, watershed nonpoint sources	Fish consumption advisory, fish tumors, degraded benthos, dredging restrictions, loss of fish habitat	Local RAP coordinator funded (Buffalo Niagara Riverkeepers); sediment and source assessment underway; 3 habitat improvement projects constructed	Haz. waste site remediation; address NPS; improve access and shore cleanup; sediment remediation	Funding; development pressures; CSOs; contaminated sediment; public involvement	Project feasibility study and implementation; beneficial use monitoring and reporting
Presque Isle Bay	3718 acre embayment	Contaminated sediments	Fish tumors, dredging restrictions	Continued brown bullhead monitoring; initiated studies to determine reference tumor incidence rates for Lake Erie and to better understand brown bullhead populations in PIB; implemented sediment monitoring program; held workshops to address fish tumor and dredging restriction BUIs.	No further remedial actions anticipated	Developing delisting targets for tumors and contaminated sediment; standardizing tumor assessment methodology	Develop delisting targets; monitor
Ashtabula River	Lower 2 miles of river	Past industrial practices; contaminated sediments; loss of habitat	Fish consumption advisory; degraded fish populations; fish tumors; degraded benthos; dredging restrictions; loss of habitat	Comprehensive Management Plan approved; landfill location selected; NRDA underway; GLLA funding approved.	Contaminated sediment remediation: habitat restoration	Funding	Prepare final remedial plan under GLLA and WRDA; monitor for improvements; implement habitat restoration under NRDA
Cuyahoga River	Lower 45 miles of river, tributaries and 10 miles adjacent nearshore. Approximately 475 sq.miles	CSOs and bypasses; urban storm water runoff; flow alterations; navigation channel; bank erosion; point sources; hazardous waste disposal sites	Fish consumption advisory; degraded fish populations; fish tumors and other deformities; degraded benthos; dredging restrictions; eutrophication; beach closings; aesthetics; loss of habitat	Stearns Farm streambank remediation; GIS wetland inventory; over 300 wetlands surveyed for quality; dam removal upstream of AOC; adoption of LTCP for Cleveland and Akron CSOs; storm water Phase 2 plans; conservation easements; TMDL; intiated feasibility of dam removal in AOC.	Increased DO and habitat restoration in navigation channel; sediment remediation in old navigation channel; long term management of navigation channel dredgings; dam removal; implementation of storm water plans	Funding for local RAP support and implementation; creating long-term stewardship	Reassessment of sub-watersheds based on Ohio delisting targets; establishment and maintenance of sub-watershed stewardship groups; installation of fish habitat in navigation channel; implementation of LTCPs; creation of additional conservation easements

AOC / Watershed Name	Geographic Area	Stressors	Beneficial Use Impairments/ Management Issues	Restoration Activities Completed (2004 & 2005)	Restoration Activities Needed	Challenges	Next Steps
Black River	Entire watershed 467 sq.mi	NPS runoff; sediment; loss of habitat	Fish consumption advisory; degraded fish populations; fish tumors and other deformities; degraded benthos; dredging restrictions; eutrophication; beach closings; aesthetics; loss of habitat; restrictions on drinking water	Redesignation of tumor BUI to "in recovery"; delisting of benthos degradation in East Branch; installation of fish shelf along lower river significantly improved habitat and the fish population; sub-watershed group established for West Branch.	Continue focus on reduction of NPS loads	Funding; public outreach and participation	Establishment of local sub-watershed groups; TMDL; additional sampling on West Branch.
Maumee River	RM 22.8 to Maumee Bay, including Duck, Otter, Cedar, Grassy, Crane, Packer, Turtle and Rusha Creeks and the Ottawa and Toussaint Rivers,636 sq.mi.	Contaminated sediments; loss of habitat; CSOs; ag and urban NPS runoff; hazardous waste sites	Fish consumption advisory; degraded fish populations; fish tumors; degraded benthos; dredging restrictions; drinking water; eutrophication; beach closings; aesthetics; loss of habitat	Toledo LTCP approved; intensive storm water and conservation education/outreach; Stage 2/watershed completed; initiated reassessment of BUIs by sub-watershed	Contaminated sediment remediation; habitat restoration; ag runoff control; wetland restoration; CSO abatement	Funding; sustained public participation; monitoring	Risk assessment for Duck/ Otter; TMDL for Swan and smaller tribs; TMDL for Toussaint; TMDL for Duck; approval of Stage 2
River Raisin	Lower 2.6 miles, 1/2 mile into lake and nearshore	Industrial and municipal discharges; contaminated sediment; water flow variability	Fish and wildlife consumption; degraded fish and wildlife; bird or animal deformities; degraded benthos; dredging restrictions; eutrophication; beach closings; degraded aesthetics; loss of habitat	240 acre Eagle Island Marsh incorporated into Detroit International Wildlife Refuge; field assessment of open waters initiated; sediment assessment of nav. channel; benthos and habitat survey	Sediment remediation; control sources of contaminants	Funding; remedial options for contaminated sediments	GLLA funding request; BUI assessment; development of fish and wildlife habitat and populations restoration targets
Rouge River	466 sq.mi. includes entire watershed	CSOs; SSOs; NPS; industrial discharges; contaminated sediment; high flow variability	Fish and wildlife consumption; degraded fish and wildlife; fish tumors; degraded benthos; dredging restrictions; eutrophication; beach closings; degraded aesthetics; loss of habitat	Legislation enacted to create Alliance of Rouge Communities; updated RAP including 20-year implementation program; monitoring showing improvement w/6 BUIs potentially eligible for removal/delisting; 77 of 83 CSOs now under control or eliminated; 32 community projects completed	Address NPS; sediment remediation; habitat restoration; manage storm water runoff.	Funding, development pressures, habitat loss	Volunteer monitoring program initiated; GIS system to map critical habitat and assist in developing fish and wildlife habitat delisting targets

AOC / Watershed Name	Geographic Area	Stressors	Beneficial Use Impairments/ Management Issues	Restoration Activities Completed (2004 & 2005)	Restoration Activities Needed	Challenges	Next Steps
Detroit River (bi-national)	32 mile connecting channel with 607 sq.mi. watershed in Michigan	Habitat loss; contaminated sediments; past industrial practices; ag runoff; urban development and subsequent storm water runoff; CSOs; non-native invasive species	Fish consumption advisories and tainting; degraded fish and wildlife populations; fish tumours and deformities; bird and animal deformities and reproductive problems; degraded benthos; dredging restrictions; drinking water taste; beach closings; degraded aesthetics; loss of fish and wildlife habitat; exceedance of water quality objectives.	Improved Cdn RAP coordination; 5-year Cdn work plan developed; Cdn delisting criteria finalized; Cdn monitoring and research plan finalized; various monitoring and research programs implemented and ongoing; 220 lbs of mercury collected under Windsor household mercury program; increased Cdn public involvement and outreach; Friends of the Detroit River reconvened US PAC; GLLA funded removal of 115,600 cu.yds contaminated sediment from Black Lagoon; >900ft. of shoreline restored; numerous ag BMPs implemented; 211 acres of upland forest habitat restored.	Ongoing implementation of large-scale monitoring program; sediment remediation; habitat conservation and restoration; address urban and rural NPS; increase public investment and involvement in the cleanup	Funding; development pressures; CSOs; contaminated sediments; insufficient public involvement; transportation issues.	Aquatic habitat management plan finalization and implementation; bi-national approval of delisting criteria; implementation of monitoring and research framework; BUI update report; expansion of household mercury collection to include pharmaceuticals; increase public involvement and awareness of RAP; creation of RAP report card.
Wheatley Harbour	Wheatley Harbour and Muddy Creek wetland in Essex Region of southwestern Ontario.	PCB contaminanted sediments; nutrient enrichment and bacteria loading from ag land use and faulty septic systems; habitat loss due to development and expansion of the commercial harbour in the 1950s and 1970s respectively.	Restriction on dredging activities; restrictions on fish and wildlife consumption; loss of fish and wildlife habitat; eutrophication or undesirable algae; degradation of fish and wildlife populations.	Wetland sediment and YOY fish sampling conducted; surface soil sampling conducted at historical dredge disposal sites; wetland hydrology and sediment transport study initiated; delisting criteria revised; 40 NPS projects conducted in Muddy Creek watershed; 5 habitat restoration projects restored 6.4 hectares of habitat; held "State of Wheatley Harbour" workshop; outfall water sampling completed.	Complete PCB source trackdown; continue to implement upstream NPS projects; complete Muddy Creek hydrology and sediment transport study.	Determining if active sources of PCBs remain in the Muddy Creek wetland; engaging local community and government.	Reassessment of BUIs; development of sediment remediation strategy; development of long-term monitoring plan; meetings with general public, local industry, and local governments to present updated status and revised delisting criteria.

AOC / Watershed Name	Geographic Area	Stressors	Beneficial Use Impairments/ Management Issues	Restoration Activities Completed (2004 & 2005)	Restoration Activities Needed	Challenges	Next Steps
Clinton River	760 sq.mi. includes entire watershed	Storm water runoff; NPS; CSOs; contaminated sediment	Fish and wildlife consumption; degraded fish and wildlife populations; degraded benthos; dredging restrictions; eutropication; beach closings; degraded aesthetics; loss of habitat	Grant to develop delisting targets; assessment of contaminated sediments; storm water education; 7 watershed groups developing sub-watershed management plans and Phase 2 P2	CSO and SSO control; NPS management; superfund remediation; habitat restoration; elimination of illicit connections and failing septic systems	Funding; development pressures	Refinement of delisting criteria; RAP update; WWTP upgrades; public education
St. Clair River (binational)	40 mile connecting channel from the Bluewater Bridge to Lake St. Clair and includes the St. Clair Flats from St. John's Marsh in the west, to the southern tip of Seaway Island, and east to the north shore of Mitchell's Bay on Lake St. Clair.	Chemical spills from Industry; mercury contaminated sediment; urban and ag NPS; loss of fish and widlife habitat	Restrictions on fish consumption and tainting; bird and animal deformities (based on chironomid mouthpart deformities); degradation of benthos; restrictions on dredging activities; restrictions on drinking water consumption and taste and odour problems; beach closings; degradation of aesthetics; added cost to agriculture and industry; and loss of fish and wildlife habitat	Removal of 13,370 cu.m. of mercury-contaminated sediment; replacement of fish mix offshore of Dow Chemical Canada Inc.; NPS pollution control programs and aquatic and terrestrial habitat restoration/enhancement on private and industry owned lands; progress report completed; RAP implementation committee reformed; receipt of federal grant for real-time water monitoring.	Address remaining mercury-contaminated sediment in Zones 2 and 3 and NPS pollution; identify potential for further aquatic habitat restoration projects; further assess effect of contaminants on bird and animal deformities and reproductive problems; develop chemical spill control and notification procedures; CSO and SSO control; NPS management.	Preventing industrial chemical spills to the St. Clair River and establishing suitable delisting criteria; understanding causes of beach closings and NPS pollution; restoring and protecting existing terrestrial and aquatic habitat in spite of continued urban and agricultural pressures; funding; interagency/ industry coordination.	Assessment of all BUIs and their delisting criteria with review by all agencies, the BPAC and the RAP Implementation Committee; additional contaminant monitoring and affects studies that will address degradation to benthos, fish consumption advisories and bird/ animal deformities; host facilitated workshop to comprehensively assess habitat gains and losses in the AOC, identify potential for aquatic restoration and review the delisting criteria; develop user-friendly report card.

AOC / Watershed Name	Geographic Area	Stressors	Beneficial Use Impairments/ Management Issues	Restoration Activities Completed (2004 & 2005)	Restoration Activities Needed	Challenges	Next Steps
WATERSHEDS							
Kettle Creek	520 sq.km watershed in southwestern Ontario, drains south London and St. Thomas to Port Stanley on Lake Erie	Highly erodable soils and steep run-off landscape; agricultural and urban development pressures	High sediment, nutrient and bacteria loadings; ag NPS pollution; river hydrology (flash flooding, low base flow); habitat degradation	$250,000 worth of environmental rehabilitation works including tree plantings, watercourse buffers, wetland creation, streambank erosion control, environmental education, watershed cleanup days, and resource managment planning at the community and municipal level.	Monitor point and NPS pollution and habitat changes, evaluate results and target remedial work for measurable results.	Need to develop and implement monitoring, protection, and restoration activities that are required to address priorities at all three levels of government - which overlap in impacts to Lake Erie.	Complete Source Protection Planning intiatives that will identify areas of NPS pollution.
Big Otter Creek, Big Creek, Lynn River, Nanticoke Creek, Sandusk Creek and Stoney Creek	Approximately 2782 km2, and includes approximately 170 km of Lake Erie shoreline entering Lake Erie east & west of Long Point.	Erosion	High sediment, nutrient, and bacteria loadings have resulted in fish and wildlife habitat loss; pathogen problems have resulted in waterfowl mortality in Long Point Bay; seasonally low water levels.	400 acres replanted/restored; restored 60 acres of acquired floodplain agricultural land along Big Creek; acquired 79-acre parcel of floodplain/wetland + 85 acres of upland forest and agricultural land; developed a restoration action plan for lower Big Creek watershed	Source water protection planning; "state of watershed" monitoring and reporting for Big Otter and Big Creek watersheds; surface & ground water monitoring programs		Private landowner extension and stewardship efforts will be a high priority in identified subwatersheds suffering erosion and sedimentation problems, and utilizing new funding as available from provincial and federal programs.
Catfish Creek	490 sq km watershed in southwestern Ontario, draining south to Port Bruce on Lake Erie	Continued agricultural and urban development pressures resulting in nutrient and sediment loading; habitat loss; and increased flooding in the lower reaches	High sediment, nutrient and bacteria loadings; ag and urban NPS pollution; habitat loss & degradation; flooding of lower watershed	Elgin Landscape Strategy completed to help identify habitat restoration sites; over $400,000 generated for special environmental rehabilitation projects and inventories.	Local watershed studies to better target areas of concern; identify, monitor, and address point and NPS pollution and habitat changes	Land use pressures; funding for watershed strategies, monitoring and implementation measures.	Complete Source Protection Planning initatives that will identify areas of NPS pollution; work in partnership with Environment Canada and other affected government agencies to identify and implement restoration and monitoring activities needed to address land use impacts on Lake Erie.

AOC / Watershed Name	Geographic Area	Stressors	Beneficial Use Impairments/ Management Issues	Restoration Activities Completed (2004 & 2005)	Restoration Activities Needed	Challenges	Next Steps
Grand River	6800 sq.km. Watershed in central SW Ontario	Urban growth and ag development pressures	Need to connect watershed issues with Lake Erie needs; impaired fish habitat;	Implementation of Grand River Fisheries Management Plan; COA assessment work on S. Grand; "Exceptional Waters" implementation; Mill Creek stewardship ranger rehabilitation; recovery team for fishes at risk; more than 1300 projects implemented under Rural Water Quality Program; removed 3 dams; Grand River and tributaries Instream/Environmental Flows Study; sub-watershed plans initiated, completed and/or implemented	Increase forest cover in the watershed from 19 to 30%; completion of source water protection plan; integrated watershed monitoring program;	Funding; addressing pressures of growth on water supply, water treatment and the environment; magnitude of rural NPS problem; coodination among federal, provincial and municipal programs for implementation	Develop integrated agency funding mechanism; implementation of GRFM, sub-watershed plans; GRSimulation model refinement; complete Grand S. Grand River assessment and initiate recommendations;
Essex Region Watersheds	425,000 acre (172,000 hectare) watershed in extreme southwestern Ontario. This peninsular region is surrounded on three sides by the Detroit River, Lake St. Clair and Lake Erie and is drained by 20 watersheds.	Land use pressures, including urban and agricultural impacts on natural lands and water quality.	Additional funding to increase NPS and habitat improvement projects; more integrated and/ or additional watershed studies to better target remedial work; require ongoing municipal engagement to address land use issues	Over 100 water quality improvement projects completed utilizing landowner incentive grants, over 200 acres of forest lands restored utilizing over 170,000 trees, over 20 community events engaging over 1,500 adults and youth, and almost 280 acres of significant natural areas protected through acquisition.	Despite ongoing progress an increased annual number of water quality improvement and habitat restoration projects are required to address local goals of 12% natural areas coverage and acceptable water quality.	Land use pressures; resources for watershed stewardship activities; imperfect integration of natural resource management activities across the region.	Aggressive pursuit of resources (funding, landowners, etc.) to restore habitat and water quality with concurrent emphasis on prevention of same in the future through landowner education and effective partnerships with muncipalities, other governments, etc.

AOC / Watershed Name	Geographic Area	Stressors	Beneficial Use Impairments/ Management Issues	Restoration Activities Completed (2004 & 2005)	Restoration Activities Needed	Challenges	Next Steps
Lake St. Clair Watershed Initiative	Canadian watershed (excluding St. Clair River) and US watershed, including St. Clair River	Land use; point and NPS source pollution; commercial & recreational boating; habitat and biodiversity loss; pathogens; spills	Degradation of fish and wildlife habitat; reduced water quality; fish consumption advisories; beach closings; chemical spills; altered hydrology; lack of defined environmental preformance measures and requisite monitoring data; stable organizational support	Lake St. Clair Coastal Habitat Assessment complete; Lake St. Clair Canadian Watershed Draft Technical Report; USACE Comprehensive Mgt. Plan for lake and river; completed consultation of proposed Cdn Management Recommendations; US TMDL for Metro & Mem. Beach begun; St. Clair Shores PCB source track down; US Lake St. Clair Regional Monitoring Project; flow modeling on the St. Clair River, Detroit River, and Lake St. Clair; third biennial Lake St. Clair Conference; Lake St. Clair Bi-national Coordinating Councils established; US Management Plan Implementation Strategy development	Detailed topographic map of lake bottom and 3D hydrological model of the Huron - Erie corridor to facilitate implementation of restoration activities; BMPs for NPS pollution; support for Lake St. Clair Coordinating Teams; development of environmental endpoints; support for implementation of USACE Management Plan	Funding; undefined measurable environmental endpoints; lack of mechanisms to ensure long-term implementation of USACE Management Plan	Complete management recommendations and develop implementation strategy; initiate US St. Clair River/Lake St. Clair drinking water monitoring project; continue Lake St. Clair Coordinating Teams' management activities
Thames River Watershed	5825 km2 watershed in southwestern Ontario, river is 273 km long, drains into Lake St. Clair	Continued land use pressures (agricultural and urban development) resulting in nutrient and sediment loads and habitat loss.	Additional funding to increase NPS projects and habitat improvement projects to address Lake Erie needs; need local watershed studies to better target remedial work.	204 rural best management projects, watershed education for 40,000 students, 120,000 trees planted for habitat improvement, local resource management plans developed or in progress, protection and rehabilitation of significant habitat.	Address NPS pollution, habitat improvement and further studies to understand source of pollution.	Land use pressures degrading watershed resources; lack of funding for watershed plans; limited monitoring and implementation.	Implementation or protection, restoration and monitoring activities need to be increased to address land use pressures and Lake Erie impacts.

Section 10: Assessment and Tracking Progress

Photo: Upper Thames River Conservation Authority

10.1 Introduction

Surveillance and monitoring provide essential information about the state of the Great Lakes ecosystem and measure the success of remediation and protection efforts. The Lake Erie LaMP is responsible for setting goals and identifying management actions to restore and protect the lake, and to track progress towards these goals. Lake Erie Ecosystem Management Objectives have been finalized and once indicators are developed, wherever possible, existing surveillance and monitoring programs will be used to track indicator changes. Where gaps in current programs exist, new programs may be developed.

In 2000, an inventory of monitoring programs in the Lake Erie basin was developed by Environment Canada based on a number of sources of information. Ninety-three independent monitoring programs were underway within the basin. These can be roughly divided into five monitoring categories (Table 10.1). Some of these monitoring programs are lakewide in nature. Others are more localized or created for a single specific purpose. Several of the monitoring programs that are more lakewide-oriented are described below. At this point, these are only examples of some of the programs that the Lake Erie LaMP may utilize, as the LaMP has not yet determined exactly how progress toward meeting LaMP goals will be tracked. Descriptions of several other monitoring programs are presented in other sections of the document.

Table 10.1: Summary of Ongoing Monitoring Efforts in Lake Erie in 2000

Monitoring Category	Number of Programs
Monitoring inputs/outputs of contaminants	19
Ambient contaminant (spatial, temporal, multimedia)	29
Populations (native and exotic) and habitat	34
Health effects monitoring	8
Exotics effects monitoring	10
TOTAL	**93**

10.2 Lake Erie Collaborative Comprehensive Survey (ECCS)
(Prepared by: Jan Ciborowski, University of Windsor)

In 2003, the Binational Executive Committee of the Parties to the Great Lakes Water Quality Agreement developed a plan for the US and Canadian agencies to jointly carry out an intensive, coordinated sampling effort on each of the Great Lakes on a 5-year rotating basis. Lake Erie was chosen for investigation in 2004 as the need for intensive sampling was especially important. In the 1990s, the water quality of Lake Erie was under pressure from low water levels coupled with infrequent but intense heavy rainstorms that caused rivers to flood and carry excess sediments and nutrients into the lake. The inadvertent introduction of exotic species such as the zebra mussel was also taking a toll.

Within the lake itself, zoobenthic composition, abundance, and distribution have become dramatically altered either because of, or together with the establishment of non-native zebra and quagga mussels (Dreissenidae) beginning in the early 1990s. Dreissenids may be abundant enough in Lake Erie to regulate phytoplankton production, and they are becoming increasingly important in the diet of both sport fish (such as smallmouth bass) and invading species (round gobies). Dreissenids are also affecting the distribution of other benthic organisms, such as aquatic insects, crayfish, and other shallow-water (*Gammarus*) and deepwater (*Diporeia*) crustaceans. These changes are expected to influence the growth of both bottom-feeding and plankton-feeding fish populations.

The water quality models used to predict the amounts of nutrients and concentrations of oxygen in the water are becoming increasingly inaccurate. This may be due to the influence of non-native invasive species, climate change, or the need for better measurements of the way water circulates, mixes, and carries materials to different parts of the lake.

As part of the collaborative effort, a study team of five scientists from Environment Canada, University of Waterloo, Ontario Ministry of Natural Resources and the Great Lakes Environmental Research Laboratory undertook intensive observations of key physical processes and water quality measurements throughout the lake during the ice-free period from April to October 2004. The goal was to obtain time-series observations for surface meteorological components, currents, water temperature and water quality parameters to better understand how weather patterns affect water movement. A total of 26 moorings of current meters, meteorological buoys, water quality recorders, sediment traps and thermistors were deployed at several locations in the lake. Other measurements were made to study nearshore-offshore horizontal exchanges and mixing along the north shore of Lake Erie to understand the mechanisms of upwelling and oxygen depletion, and the impact of storms on resuspension and transport of the material.

Between May and August 2004, a team of 23 scientists from Canadian and US universities and agencies, coordinated through the Lake Erie Millennium Network, collected bottom-dwelling organisms and sediments, and measured water chemistry. A total of 284 nearshore and offshore stations were sampled from 10 different vessels through the cooperative efforts of Environment Canada, Ontario Ministry of the Environment, Ontario Ministry of Natural Resources, NOAA, the USGS, and other cooperators (the Lake Erie Comprehensive Collaborative Study - ECCS). The sample locations were allocated among the three basins, four depth classes, and two substrate types (hard/soft) to permit lake-wide estimates of benthic invertebrate abundance and biomass, especially for zebra and quagga mussels.

Hard substrates were sampled by divers operating air lift samplers. Soft substrates were sampled with a standard Ponar grab. In addition to collecting bottom-dwelling invertebrates, sediment and bottom-associated algal samples were collected at 174 locations where soft sediments were found. The physical and chemical characteristics of these sediments were analysed as were the concentrations of trace metals, organochlorine compounds, and other chemicals of emerging environmental concern.

Funding was provided by U.S.EPA-GLNPO, Ontario Ministry of the Environment, and Environment Canada to process, identify, enumerate and determine the biomass of zoobenthos, especially dreissenids, in benthic samples. The organisms from each station were identified to the genus or species level and enumerated. The biomass of dreissenid mussels was also determined.

Preliminary Results

Lake-wide, quagga mussels were much more common and abundant (mean abundance and density of 2,530 individuals/m^2; 43 g/m^2 dry mass) than zebra mussels (242 individuals/m^2 and 1.9 g/m^2 dry mass). Both species were about equally abundant at shallow depths (<8 m) in the western basin, but zebra mussels were found at only seven of 116 central basin stations, and one of 81 eastern basin locations. Maximum densities were recorded at depths of 3-7 m, 8-12 m, and 8-29 m in the western, central, and eastern basins, respectively. The total density and mass of dreissenids has changed little since 1992, but zebra mussels are now confined almost entirely to the western basin. The density of quagga mussels in the eastern basin may have declined between 2002 and 2004, but biomass was unchanged. Over 75 percent of dreissenid numbers and an even greater percentage of the biomass now occur in the eastern basin. Deepwater amphipods (*Diporeia*), which are an important food for lake whitefish and other bottom-feeding fishes, were collected at only four stations. Taken together, these data suggest that the distribution and abundance of benthic invertebrates in Lake Erie continues to change in concert with the changing aquatic environment and pressures of their predators.

The results of measurements of water movements made in 2004 and additional measurements collected in 2005 are still being interpreted. Preliminary analyses indicate that the average direction of transport was unidirectional and followed the path of prevailing winds from west to east. However, at some times, water near the lake bottom flows from the eastern basin (where most of the dreissenids are located) into the central basin. Further work is needed to determine how much phosphorus associated with dreissenid excretion may be carried by these flows. Water, nutrient, and particle transport movements associated with several severe storm events were recorded and are revealing some unexpected and interesting patterns of circulation.

Throughout the biological and water movement studies, special care was taken to ensure that all data collected and compiled were compatible and suitable for use by other scientists. Ultimately, this information will be incorporated into statistical models that will help us better understand the way in which the lake's physical properties and processes are coupled with biological conditions to affect the Lake Erie food web.

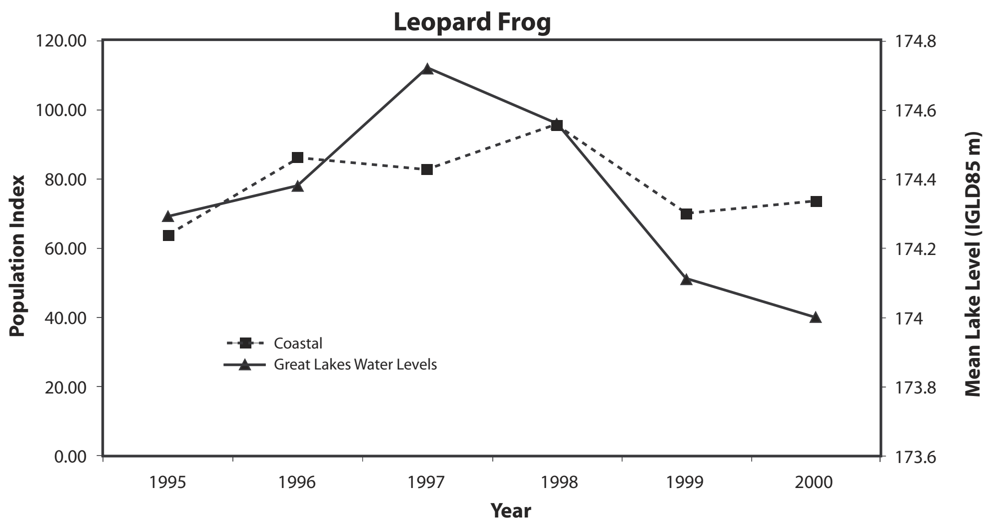
Photo: U.S. Fish & Wildlife Service, Mike Weimer

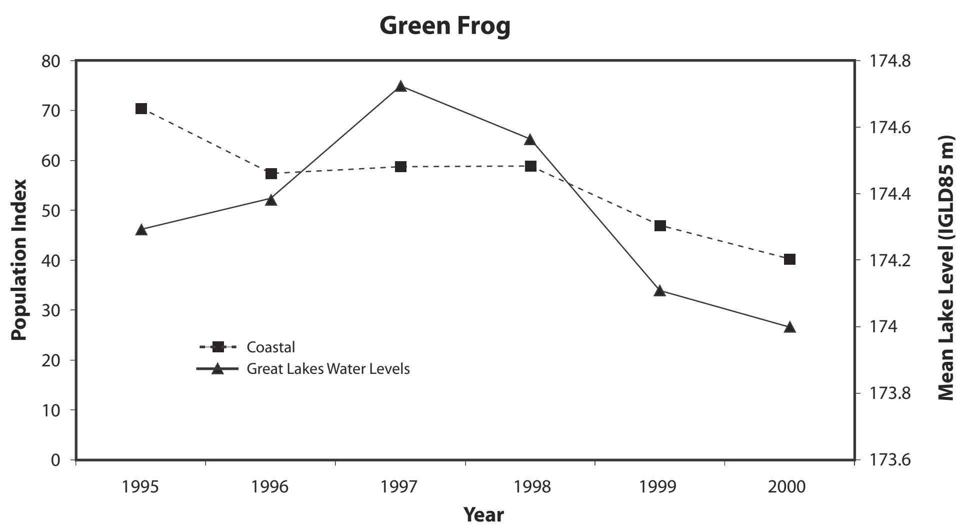
10.3 Marsh Monitoring Program
(Reproduced from Lake Erie LaMP 2002 report)

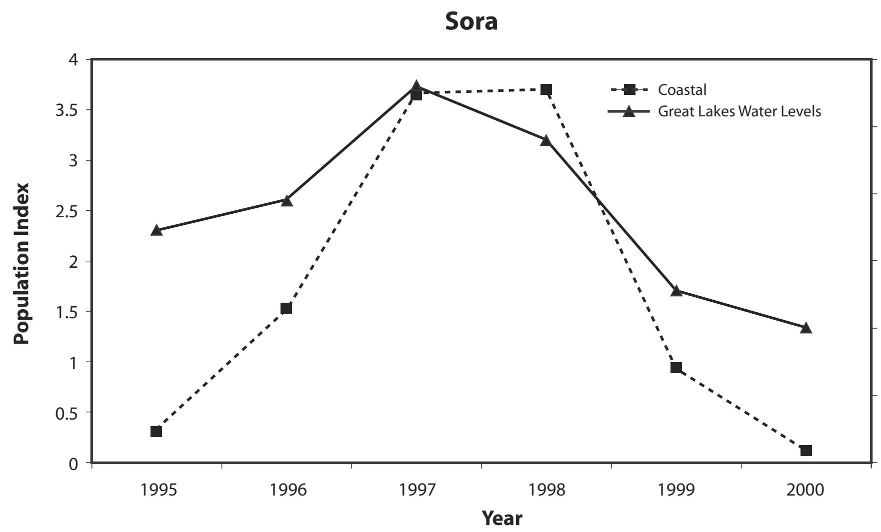
Since 1995, this volunteer based program has engaged both professional and dedicated citizen naturalists throughout the Great Lakes region (including Lake Erie) to record and monitor annual trends in populations of several calling-amphibian (frogs and toads) and marsh bird species in important marshes throughout the basin. Information gathered through the Marsh Monitoring Program is relevant for assessing relative population changes in these species at local, regional and basinwide scales, and can be useful for gauging the status and ecological integrity of marshes at each of these scales.

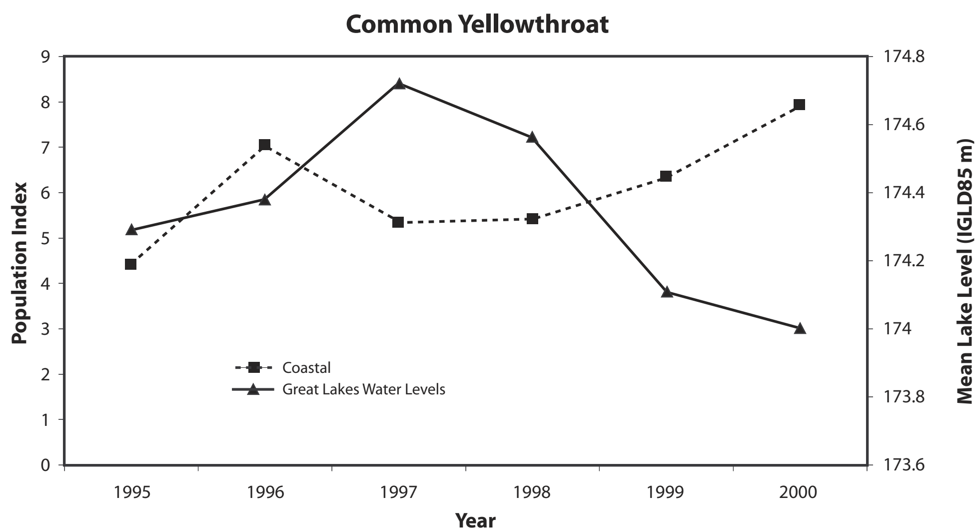
Results (1995-2000) suggest that there appears to be a relationship emerging between population trends of some marsh bird and amphibian species in coastal marshes and the trend in Lake Erie's mean annual water levels, especially since 1997, the year that marked the end of the last sustained high water period. For example, black tern and sora trends at coastal marshes have followed a similar pattern to that of Lake Erie's water levels. Similarly, trends for aquatic amphibian species such as green frog and northern leopard frog have closely reflected the trend in Lake Erie's water levels at coastal marshes. Conversely, trends for certain marsh bird species preferring drier marsh edge habitat have increased at coastal marshes during recent lake level declines. For example, the trend for common yellowthroat (a marsh edge preferring warbler) at coastal Marsh Monitoring Program routes has been inversely related to Lake Erie's water levels (Figure 10.1).

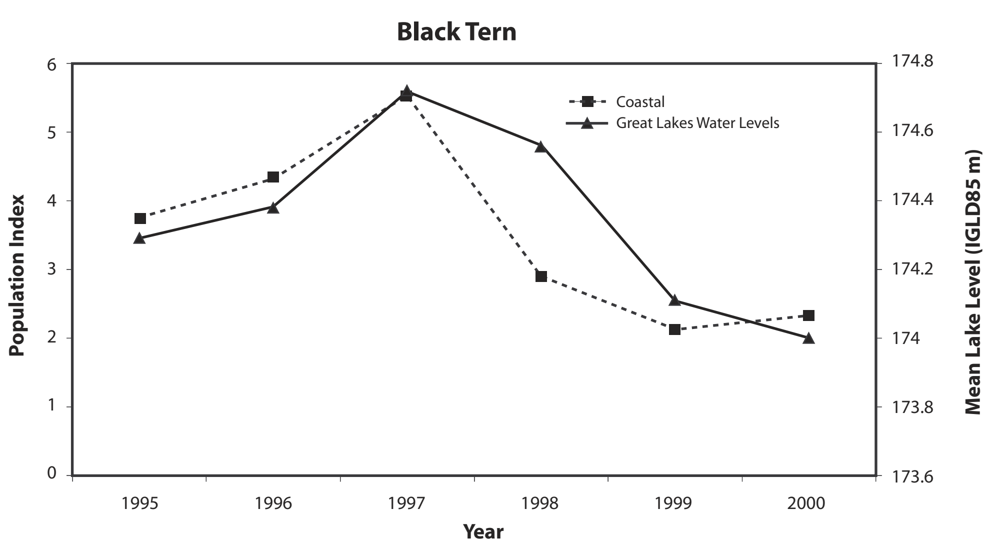
Figure 10.1: Lake Erie basin-wide trends in relative abundance of selected marsh bird and amphibian species compared to mean annual water levels of Lake Erie from 1995 to 2000. For each species, trends are presented for marshes monitored at coastal locations (i.e. within 5 km/3 miles from a lake shore).






Sora
Coastal
Great Lakes Water Levels
Population Index
Year
4
3.5
3
2.5
2
1.5
1
0.5
0
174.8
174.6
174.4
174.2
174
173.8
173.6
1995
1996
1997
1998
1999
2000


Common Yellowthroat
Coastal
Great Lakes Water Levels
Population Index
Mean Lake Level (IGLD85 m)
Year
9
8
7
6
5
4
3
2
1
0
174.8
174.6
174.4
174.2
174
173.8
173.6
1995
1996
1997
1998
1999
2000


Black Tern
Coastal
Great Lakes Water Levels
Population Index
Mean Lake Level (IGLD85 m)
Year
6
5
4
3
2
1
0
174.8
174.6
174.4
174.2
174
173.8
173.6
1995
1996
1997
1998
1999
2000

Bald Eagle Update

Bald eagles continue to be a highly visible indicator of the state of the Great Lakes. Most of the bald eagles nesting in the Lake Erie basin are found in Ohio, particularly in the marshes in the western basin. In 1979, Ohio had only four nesting pairs along the southwestern Lake Erie shoreline and the eagles along Ontario's Lake Erie shoreline produced no young. Exposure to pesticides, particularly DDT and its breakdown product DDE, proved to be the barrier to successful bald eagle reproduction. Reduction in pesticide use slowly decreased the amount of contaminants in the birds. 1980s programs of hacking healthy eaglets in nests in the western basin marshes, and transplanting healthy adult bald eagles to the Long Point area have greatly improved the population status.

The 2000 nesting year was excellent for Ohio Lake Erie eagles with an 83% success rate and an average 1.4 fledglings per nest. 63 nesting pairs produced 89 fledglings (ODNR). In 2000 the Ontario shore of Lake Erie fledged 21 birds from 14 nests, a rate of 1.5 fledglings per nest (Whittam 2000). Eagle populations continue to grow both along the shore and further inland. Younger birds are starting to build nests closer to human disturbance, and more nests are being found further east and inland. In 2002, 107 eaglets fledged from 58 nests statewide in Ohio. In 2003, 88 nesting pairs in 34 (out of 88) Ohio counties produced 105 young. A record-breaking 105 bald eagle nests have been documented in Ohio statewide at the beginning of the nesting season in 2004.

Photo: U.S. Fish & Wildlife Service, Dave Menke

Although populations continue to increase, the inland populations are increasing faster than the Lake Erie based populations. Also, although the reproductive success is improved, the birds are not living as long. Bald eagle pairs generally return to the same breeding territory, and often use the same nest. However, there appears to be a high rate of turnover for breeding birds. Bald eagles can live to be about 28 years old in the wild but the birds in the southern Great Lakes are only surviving for 13-15 years.

The Ohio Lake Erie Protection Fund provided a grant in 2000 to analyze blood and feather samples collected and archived by the Ohio Department of Natural Resources in the 1990s. PCBs, DDE, chlordane and dieldrin are still found at significant levels (Roe et al. 2004). Elevated levels of mercury and lead have been found in birds in the Long Point area on the Canadian shore. Additional research by Bird Studies Canada and the Ontario Ministry of Natural Resources is being done to track sources of mercury and lead in the bald eagles' diet.

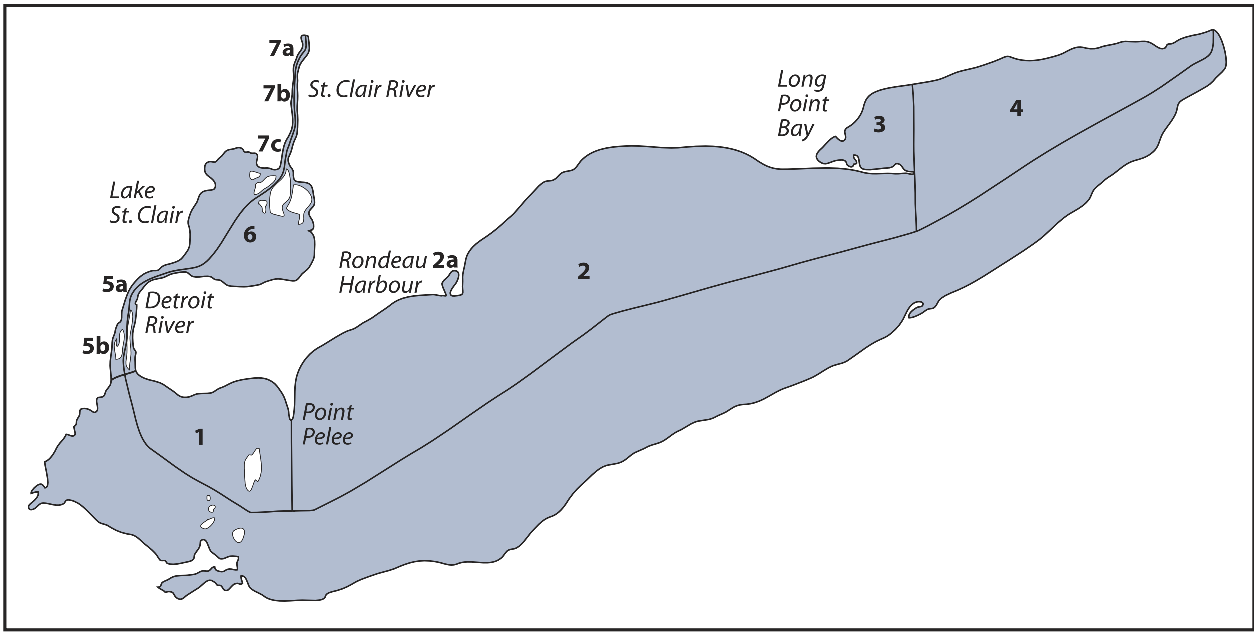
These relations could be explained in part by spatial movement of certain species into or out of Marsh Monitoring Program survey routes. Alternatively, as lake levels declined, if appropriate marsh habitat was not replaced at the rate at which it was lost, and appropriate marsh habitat was either not available elsewhere or was already at its carrying capacity, then declining trends in highly marsh dependent birds and amphibians may well be indicative of overall population declines.

Although current lake levels are near their long-term lows, because lake levels fluctuate, and trends in certain marsh bird and amphibian species at coastal marshes appear to respond to changing lake levels (positively or negatively), when Lake Erie's levels begin to increase again, these responses should be detected by Marsh Monitoring Program data. Only by taking into account the dynamic nature of coastal marsh habitats can one examine what is really happening to populations of marsh birds and amphibians in the Lake Erie basin.

10.4 Trends in Contaminants in Ontario's Lake Erie Sport Fish *(Reproduced from Lake Erie LaMP 2002 report and updated in 2004, prepared by Al Hayton, Ontario Ministry of the Environment)*

Sport fish contaminant monitoring in Ontario is coordinated by the Ontario Ministry of the Environment and conducted in partnership with the Ontario Ministry of Natural Resources. Sport fish from the Canadian waters of Lake Erie have been monitored on a regular basis for contaminants since the 1970s. Size and species-specific consumption advisories for different regions or blocks of the lake (Figure 10.2) are provided to the public in the *Guide to Eating Ontario Sport Fish*.

Figure 10.2: Lake Erie blocks



Consumption advisories, provided as the recommended maximum number of meals per month, are based on health protection guidelines developed by Health Canada. Consumption restrictions in Ontario on Lake Erie sport fish are caused by PCBs (82%) and mercury (18%). In 2002 these percentages were 70% and 30%, respectively. Other contaminants such as DDT and metabolites, hexachlorobenzene, octachlorostyrene, chlordane and lindane are often detected in Lake Erie sport fish, but do not cause consumption restrictions, and concentrations have declined over the years. In recent years, dioxins and furans have been monitored in species expected to have the highest concentrations (e.g. carp, lake whitefish), but have not caused consumption restrictions. Comparing data across the Canadian waters of the Great Lakes, Lake Erie has the lowest proportion of sport fish species with consumption restrictions at 15.7% (in 2002 that number was 17.4%). The proportion of sport fish species with consumption restrictions in the Canadian waters of the other Great Lakes ranges from 21.1% in Lake Huron to 41.1% in Lake Ontario.

In order to report on spatial and temporal trends in contaminants, a "standard size" was selected for each species. The standard size was close to the mean length for the species in the database and typical of the size caught and consumed by anglers. Contaminants in standard size sport fish for the last 10 years were used to evaluate spatial trends. Contaminant data from Block 1 from 1976-2000 were separated into 5-year intervals for temporal trend evaluation. Species selection was based on the availability of data.

Mercury concentrations exhibit no spatial patterns across Lake Erie blocks. Mercury concentrations in 30 cm white bass ranged from 0.09 to 0.15 ppm and in 45 cm walleye from 0.10-0.13 ppm. For both species there was no significant difference across the three major blocks of Lake Erie (Figures 10.3 and 10.4). Block 3 (Long Point Bay) was excluded from the statistical analysis because of the lack of replicate data. Over the past 25 years, mercury concentrations in Lake Erie sport fish have declined. When a comparison was made of the mercury concentrations in white bass in five year intervals between 1976 and 2000 it was found that mean concentrations in 30 cm white bass decreased significantly from 0.22 ppm in the first period (1976-1980) to 0.13 ppm in the last period (1996-2000). The same was found for walleye. Mean mercury concentrations in 45 cm walleye decreased from 0.30 ppm to 0.12 ppm in the same time period (Figures 10.5 and 10.6). Most of the decrease occurred between the 1976-1980 period and 1981-1985. Between 1981-1985 and 1996-2000, there was no significant difference in mercury concentrations in either white bass or walleye. Mercury concentrations in most Lake Erie sport fish are low and only the largest individuals tend to exceed the consumption guideline of 0.45 ppm. White bass and walleye do not exceed the guideline until they exceed 40 cm and 70 cm in length respectively (Figure 10.7).

Analysis of spatial patterns of PCBs for 30 cm white bass suggests that there is little difference in PCB concentrations between blocks in Lake Erie (Figure 10.8). Lower levels found in block 4 are based on only one year of data so statistical significance could not be determined. Over the past 25 years, PCB concentrations in some but not all species of Lake Erie sport fish have decreased. Mean PCB concentrations in 30 cm white bass decreased significantly from 615 ppb in 1976-1980 to 242 ppb in 1996-2000 (Figure 10.9). Most of the decrease occurred between the 1976-1980 and 1981-1985 periods.

PCB concentrations in channel catfish appear to have decreased (Figure 10.10) but lack of replicate data for some periods prevented statistical confirmation. The highest PCB concentrations were found in 1981-1985 (3225 ppb). By the 1996-2000 period mean PCB

Figure 10.3: Mercury concentrations in 30 cm (12 inch) white bass across Lake Erie 1990-2000

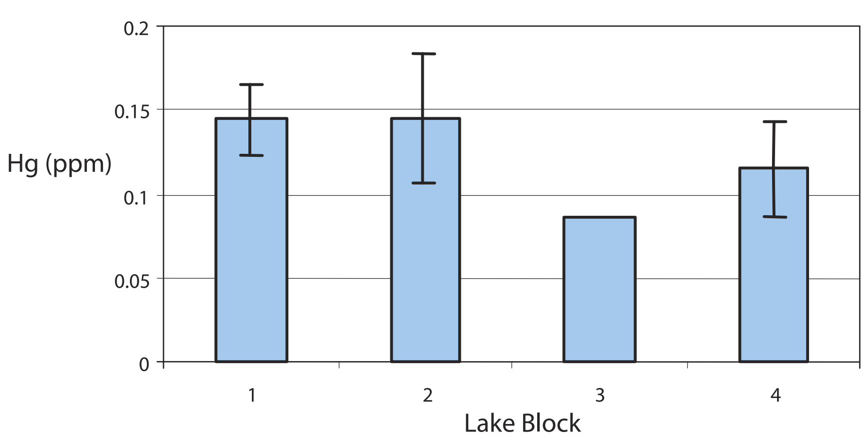


Figure 10.4: Mercury concentrations in 45 cm (18 inch) walleye across Lake Erie 1990-2000

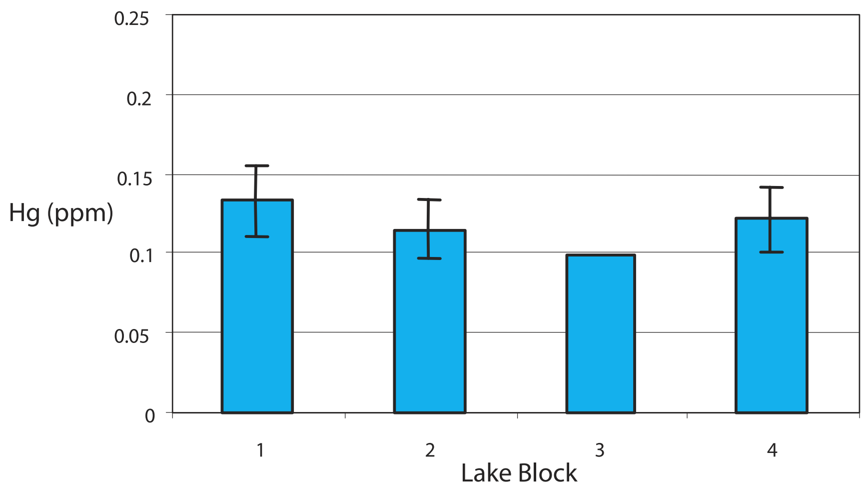


Figure 10.5: Mercury concentrations in 30 cm (12 inch) white bass over time in Lake Erie block 1

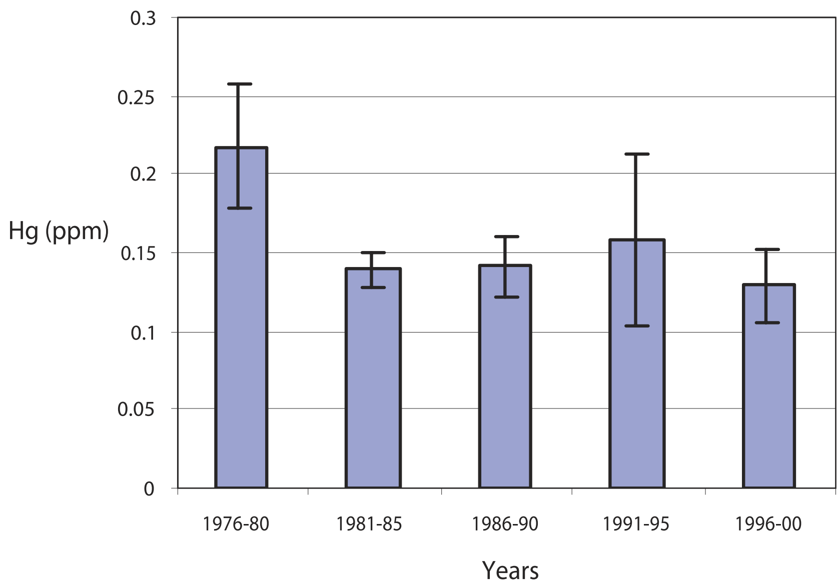


Figure 10.6: Mercury concentrations in 45 cm (18 inch) walleye over time in Lake Erie block 1

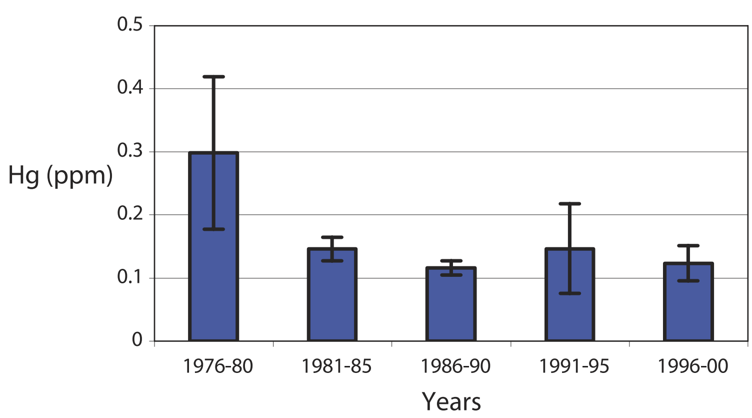


Figure 10.7: Mercury concentration vs. length in walleye and bass from Lake Erie block 1

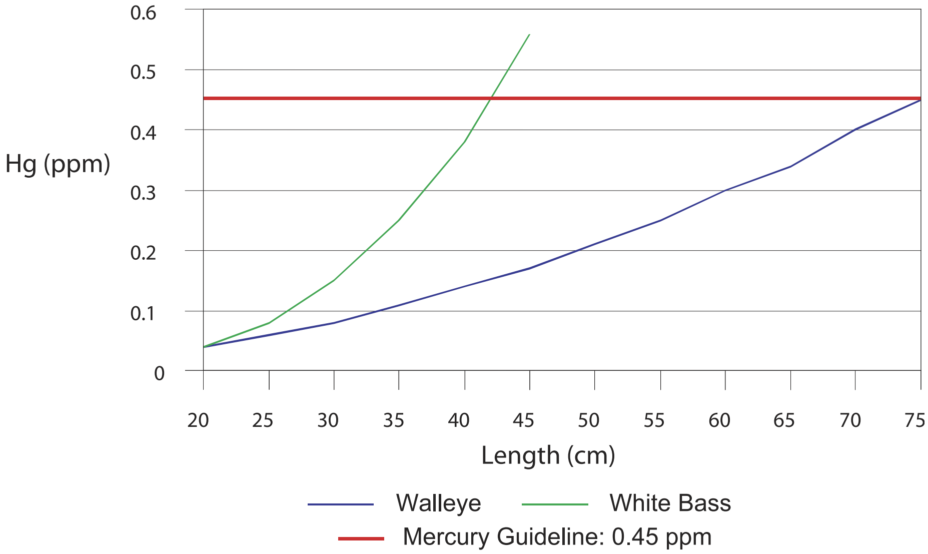


Figure 10.8: PCB concentrations in 30 cm (12 inch) white bass across Lake Erie 1990 - 2000

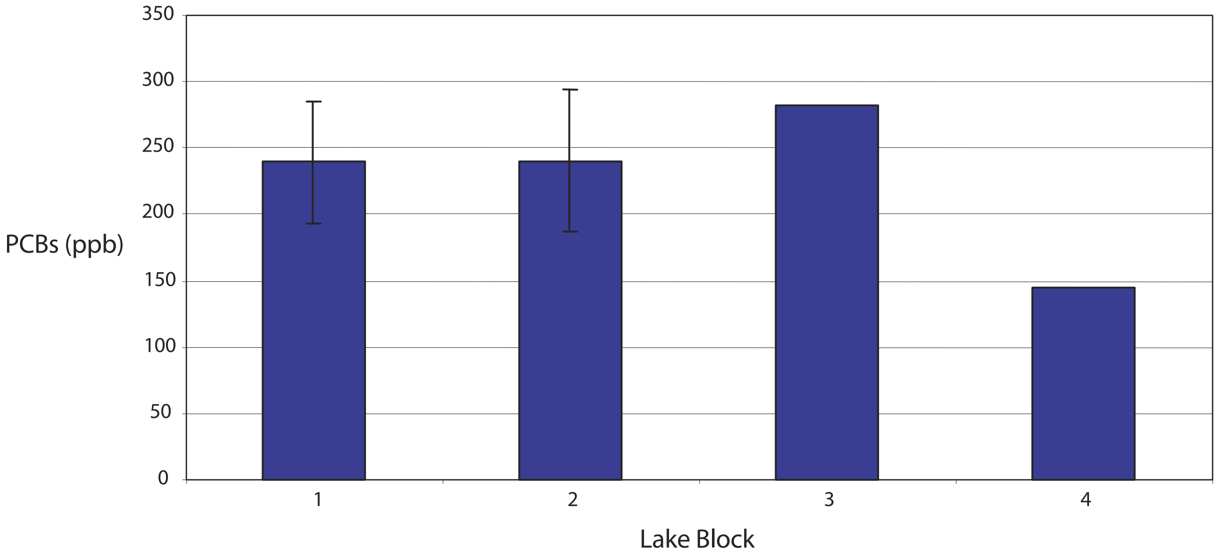


Figure 10.9: PCB concentrations in 30 cm (12 inch) white bass over time in Lake Erie block 1

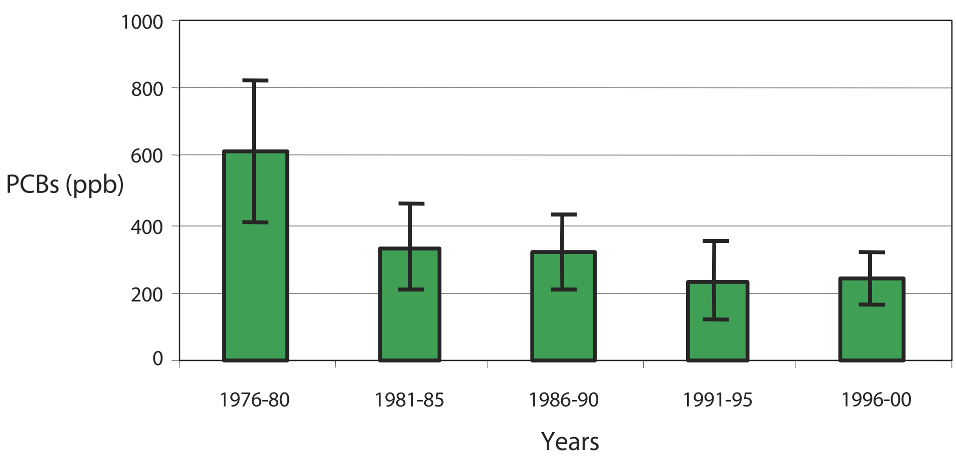


Figure 10.10: PCB concentrations in 45 cm (18 inch) channel catfish over time in Lake Erie block 1

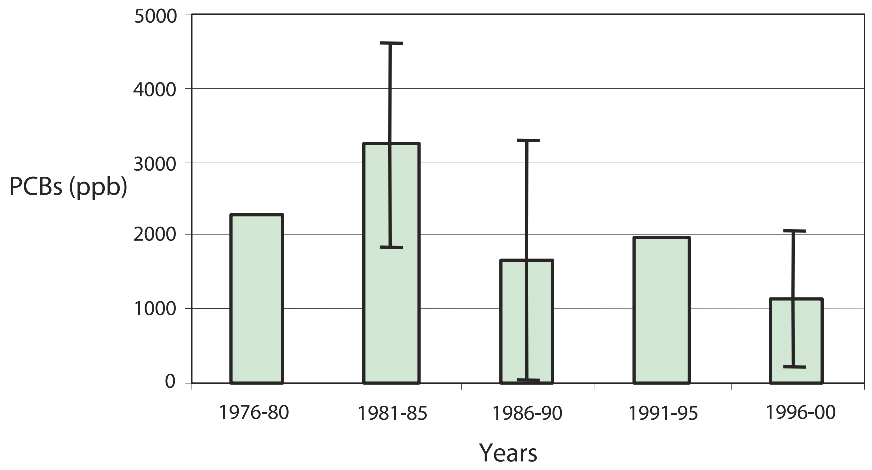


Figure 10.11: PCB concentrations in 65 cm (25 inch) carp over time in Lake Erie block 1

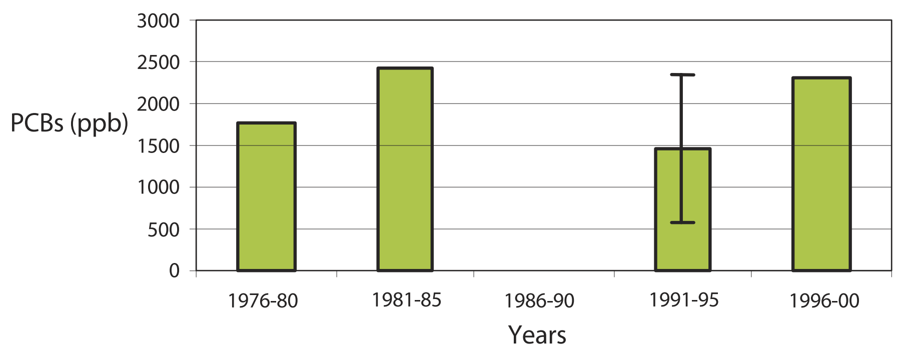
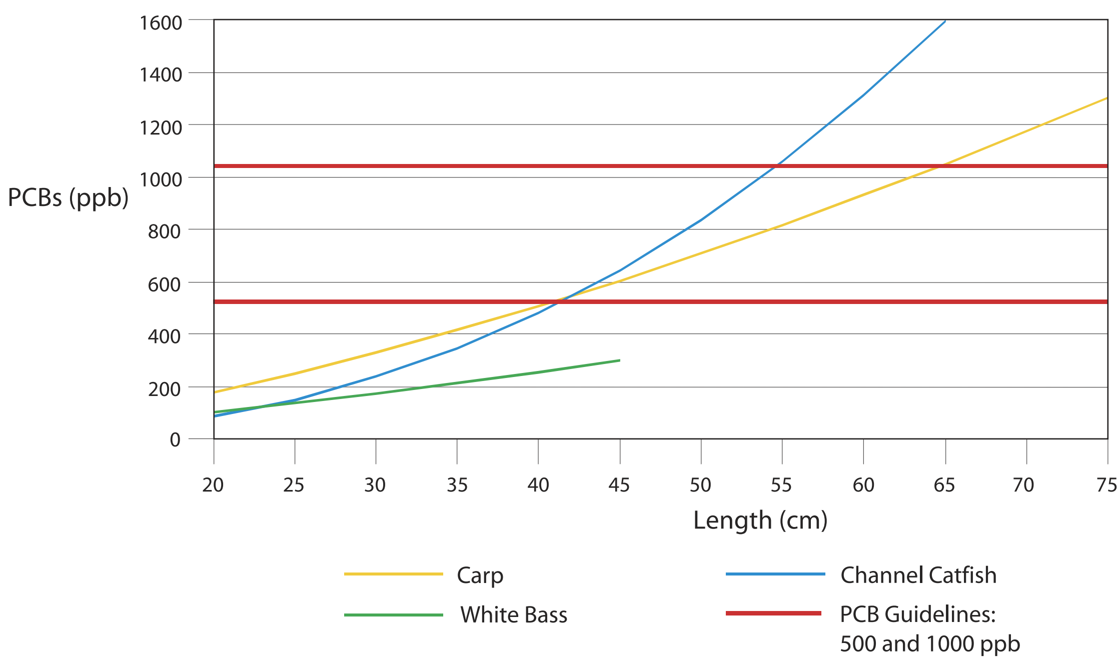


Figure 10.12: PCB concentration vs. length in fish from Lake Erie block 1



concentrations had declined to 1143 ppb. PCB concentrations in carp do not appear to have declined over the period of sampling and in the most recent period (1996-2000) were still in excess of 2000 ppb (Figure 10.11). Differences among species may be due to the residual effects of sediment-bound PCBs. Pelagic species such as white bass would be less affected by sediment-bound PCBs than benthic-feeding species such as carp. Although PCB concentrations are low in most Lake Erie sport fish, high lipid species such as channel catfish and carp exceed the consumption guideline of 500 ppb even in relatively small individuals (Figure 10.12).

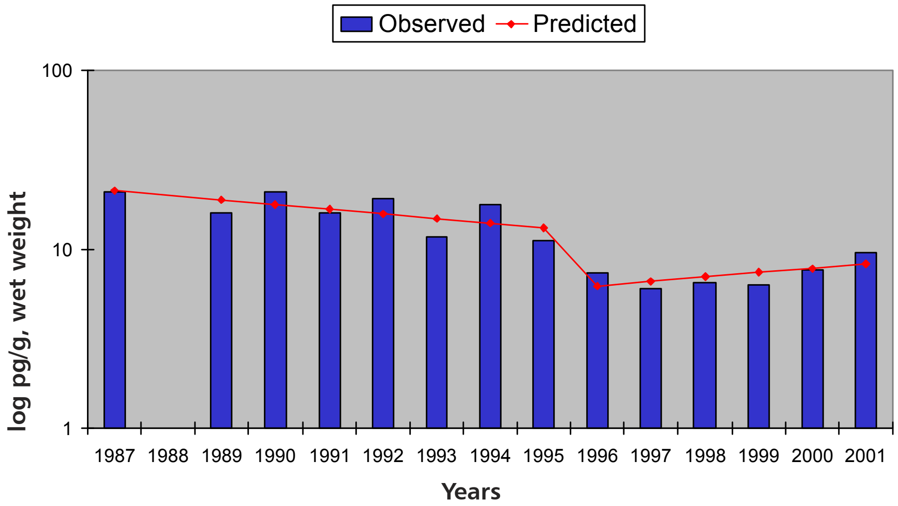
The Ontario Ministry of the Environment, through the Sport Fish Contaminant Monitoring Program, continues to monitor Lake Erie sport fish for trends in contaminant concentrations and provides consumption advice to anglers.

10.5 Trends in Contaminant and Population Levels of Colonial Waterbirds *(Reproduced from Lake Erie LaMP 2002 Report, prepared by Chip Weseloh, Environment Canada - Canadian Wildlife Service)*

The Wildlife Toxicology Section of the Canadian Wildlife Service (Ontario Region) maintains two wildlife-monitoring programs on the Great Lakes: contaminants in herring gull eggs and population levels of breeding colonial waterbirds. The former program was last reported on for the two Lake Erie sites, Middle Island and Port Colborne Breakwall, in 1999. The latter program is only conducted in its entirety once every decade and the most recent report is now available.

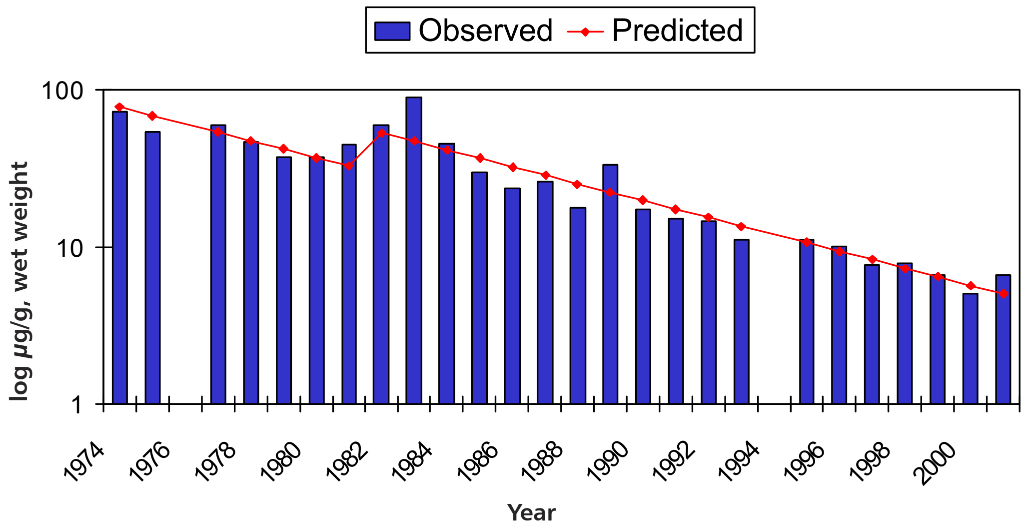
Contaminant levels in herring gull eggs do not change very much from year to year, and year-to-year changes do not necessarily have much meaning in long-term trends. Significant changes in long-term trends are usually only seen over several years. For example, Figure 10.13 illustrates an increase in 2,3,7,8 TCDD (dioxin) in herring gull eggs at Middle Island over the last three years but, compared to longer-term observations, there is not an increasing or decreasing trend. Figure 10.14 likewise shows an increase in PCB in herring gull eggs at the Port Colborne site in 2001, but the overall long-term trend is downward. The overall changes in concentrations of the other contaminants measured under this monitoring program (DDE, hexachlorobenzene, mirex, heptachlor epoxide and dieldrin) were variable over the last three years, but the overall trend is significantly downward.

Figure 10.13: 2378-TCDD in herring gull eggs - Middle I., 1987-2001



Model shows a significant decline before the change point year in 1996 and a non-significant trend after the change point.

Figure 10.14: PCB 1:1 in herring gull eggs - Port Colborne, 1974-2001



Model shows the same significant rate of decline before and after the change point in 1982.

Breeding populations of colonial waterbirds on Lake Erie were surveyed in the late 1970s, 1980s and the 1990s. During the last two decades, populations of herring and ring-billed gulls, and common terns have declined from 14.7 to 18.3%. This is consistent with similar patterns for these species in the other Great Lakes. The number of breeding gulls has declined probably as a result of artificially high population levels in the 1980s, when forage fish populations were larger. Common terns have declined probably as a result of ongoing nest site competition with ring-billed gulls. Double-crested cormorant populations in Lake Erie have increased 211% since the late 1980s. Their populations have been increasing in each of the Great Lakes since the late 1970s. Great black-backed gulls and Caspian terns have just started nesting in Lake Erie (at Mohawk Island at the mouth of the Grand River) and have not yet established themselves there on an annual basis.

10.6 Ohio Lake Erie Quality Index

In 1998, the Ohio Lake Erie Commission released the Ohio State of the Lake Report. For this report ten indicators were developed to measure environmental, economic and recreational conditions as related to the quality of life enjoyed by those living near or utilizing the Ohio waters of Lake Erie. Each indicator is composed of several metrics that were selected because they had measurable goals or endpoints against which progress could be measured and, in most cases, some regular monitoring was already being done. These indicators, called the Lake Erie Quality Index, will be updated in 2004. The ten indicators developed in 1998 are presented in Table 10.2.

Additional analysis over the past five years has somewhat altered the metrics used to determine several of the indicators. The Water Quality Indicator has been split into two indicators: one that addresses ambient conditions (water chemistry, water clarity, contaminants in bald eagles, and contaminated sediment) and one that addresses human exposure risks (fish consumption advisories, beach closings and drinking water). The biological indicator has been expanded to include an index of biological integrity (IBI) for shoreline and tributary fish, offshore fish, offshore plankton, key indicator species and coastal wetlands. Tourism and shipping have been combined into one indicator titled Economy.

Table 10.2: Ohio Lake Erie Quality Index Indicators

Indicator	Rating
Water Quality	Good
Pollution Sources	**Fair**
Habitat	**Fair**
Biological	Good
Coastal Recreation	Good
Boating	Good
Fishing	Excellent
Beaches	Good
Tourism	Excellent
Shipping	Fair

Photo: Scott Gillingwater

10.7 State of the Lakes Ecosystem Conference (SOLEC)

In response to a reporting requirement of the Great Lakes Water Quality Agreement, in 1994 U.S. EPA and Environment Canada initiated the State of the Lakes Ecosystem Conference, more universally known as SOLEC. It provides a forum for the exchange of information on the ecological condition of the Great Lakes and surrounding lands. SOLEC focuses on the state of the Great Lakes ecosystem and the major factors impacting it, rather than on the status of programs needed for protection and restoration, which is more of the LaMPs' role. In 1998, SOLEC began an effort to develop standard indicators that could be used to better report out on the status of the Great Lakes in a more consistent manner. SOLEC reviewed a number of possible indicators and is currently refining a list of 80 for their potential utility in measuring conditions across the Great Lakes. The work of the SOLEC team will be utilized wherever possible as the Lake Erie LaMP develops the indicators that it will use to track Lake Erie LaMP progress. In 2004, SOLEC will focus on indicators of physical integrity.

10.8 Trends in Contaminants in Lake Erie Whole Fish (1977-2004) *(Prepared by: Elizabeth Murphy, U.S.EPA GLNPO; D. Michael Whittle and Michael J. Keir, DFO, Great Lakes Laboratory for Fisheries and Aquatic Sciences; and J. Fraser Gorrie, Bio-Software Environmental Data)*

Long-term (>25 yrs), basin-wide monitoring programs measuring whole body concentrations of contaminants in top predator (lake trout and/or walleye) and forage fish (smelt) are collected by the U.S.EPA's Great Lakes National Program Office (GLNPO) and Fisheries and Oceans Canada (DFO) to develop trend data on bioavailable toxic substances in the Great Lakes aquatic ecosystem. DFO reports contaminant burdens annually in similarly-aged fish, while GLNPO reports contaminant burdens annually in similarly-sized fish. For Lake Erie, DFO samples walleye, lake trout and smelt 4 to 6 years old, while GLNPO samples walleye 450 to 550 mm in length. Since the late 1970s, concentrations of historically regulated contaminants, such as PCBs, DDT and mercury, have generally declined in most monitored fish species throughout the Great Lakes. Several other contaminants, currently regulated or unregulated, have demonstrated either slowing declines or increases in selected fish communities. These changes are often specific to a particular Great Lake and relate both to the characteristics of the substances involved and the biological conditions of the fish community surveyed.

The GLWQA criterion for PCBs states that, "The concentration of total polychlorinated biphenyls in fish tissues (whole fish, calculated on a wet weight basis), should not exceed 0.1 microgram per gram for the protection of birds and animals which consume fish." The GLWQA criterion for DDT and metabolites states that, "The sum of the concentrations of DDT and its metabolites in whole fish should not exceed 1.0 microgram per gram (wet weight basis) for the protection of fish-consuming aquatic birds". The GLWQA criterion for mercury states that, "The concentration of total mercury in whole fish should not exceed 0.5 micrograms per gram (wet weight basis) to protect aquatic life and fish-consuming birds". Tables 10.3 and 10.4 define the percent change over time compared to the highest recorded concentration, for GLNPO and DFO sampling, respectively.

Table 10.3: Percent Change in Total PCB/ΣDDT Concentrations for GLNPO Fish Collections (Walleye: 450-550mm)

Contaminant	GLWQA Criterion (μg/g)	Species	Highest Recorded Concentration		Most Recently Measured Concentration		% of Highest Recorded Concentration
			Year	Value (μg/g)	Year	Value (μg/g)	
Total DDT	1.0	Walleye	1977	0.51	2000	0.085	17%
Total PCBs	0.1	Walleye	1977	2.64	2000	1.241	47%

*All concentrations based on whole fish samples, wet weight

Table 10.4: Percent Change in Total PCB/ΣDDT/Mercury Concentrations for DFO Fish Collections (Age 4 to 6 year old range)

Contaminant	GLWQA Criterion (μg/g)	Species	Highest Recorded Concentration		Most Recently Measured Concentration		% of Highest Recorded Concentration
			Year	Value (μg/g)	Year	Value (μg/g)	
Total DDT	1.0	Walleye	1977	0.90	2003	0.06	7%
		Lake Trout	1989	0.83	2003	0.07	8%
		Smelt	1980	0.12	2003	0.01	8%
Total PCBs	0.1	Walleye	1979	3.11	2003	1.08	35%
		Lake Trout	1990	1.75	2003	0.70	40%
		Smelt	1990	0.76	2003	0.08	11%
Mercury	0.5	Walleye	1977	0.37	2003	0.12	32%
		Smelt	2002	0.05	2003	0.02	40%

*All concentrations based on whole fish samples, wet weight.

Total DDT

All monitored species in Lake Erie displayed a similar pattern of DDT contamination (see figures below). Each species displayed a fair degree of year-to-year variability but the overall trend is decreasing. Since the late 1970s, concentrations showed a steady decline followed by a sharp increase in the late 1980s. After 1989, concentrations again declined with some year to year variability. Figure 10.15 presents DDT in rainbow smelt (DFO), Figure 10.16 displays DDT in DFO-collected walleye, and Figure 10.17 depicts DDT in GLNPO-collected walleye. Both DFO and GLNPO walleye data follow the pattern of annual concentration increases in the late 1980s, linked to changes in the zebra mussel population (Morrison et al. 1998, Morrison et al. 2000), followed by generally declining concentrations after 1989. DFO walleye collected in Lake Erie represent primarily conditions in the western and central basins of the lake. Fall DFO collections occur in the western basin but fish migrate between the western and central basins at points during each year. Fall GLNPO walleye collections demonstrate similar characteristics. DFO lake trout and smelt data trends also follow the fluctuating concentration pattern influenced by zebra mussel infestation (Morrison et al. 1998.) It is important to note that DFO lake trout collections in Lake Erie were only initiated in 1985. Therefore, the limited number of samples available in the selected age cohort over time makes rigorous temporal trend assessment difficult. Lake trout primarily represent conditions in the eastern basin of the lake as their movement is restricted by generally higher water temperatures prominent outside the eastern basin. GLNPO and DFO recorded concentrations of total DDT in Lake Erie walleye have never exceeded GLWQA criteria. DFO recorded concentrations of total DDT in lake trout and smelt have never been above GLWQA criteria.

Figure 10.15: Total DDT levels in Lake Erie Rainbow Smelt, 1977-2004 (µg/g +/- S.E. wet weight, whole fish). (Source: DFO-GLLFAS unpublished data) GLWQA criterion is 1.0 µg/g.

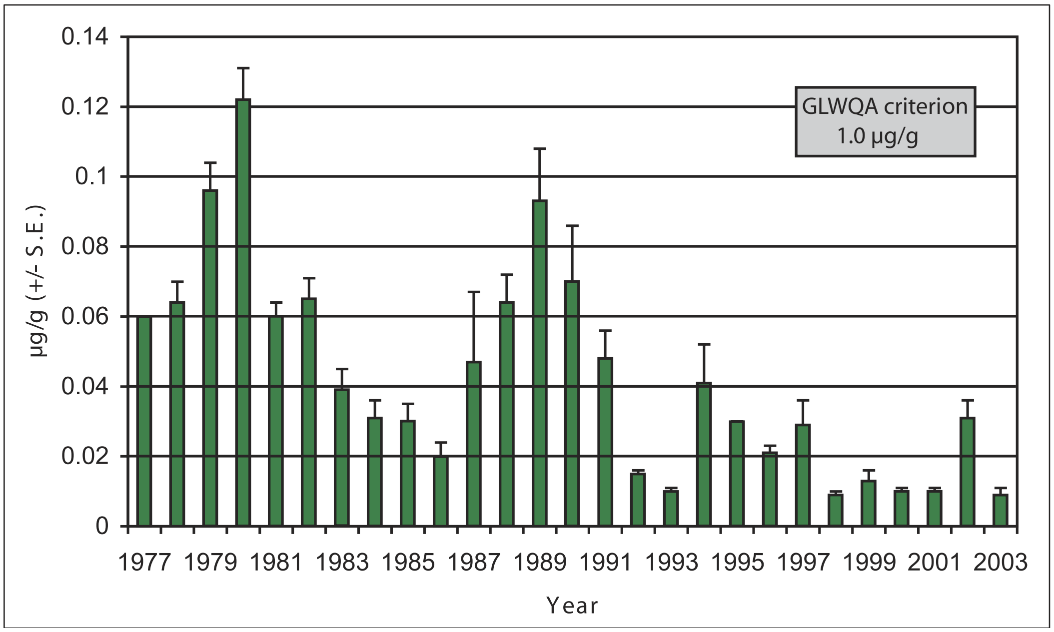


Figure 10.16: Total DDT Levels in Lake Erie Walleye, 1977-2003 (µg/g +/- S.E. wet weight, whole fish ages 4-6). (Source: DFO-GLLFAS, unpublished data)

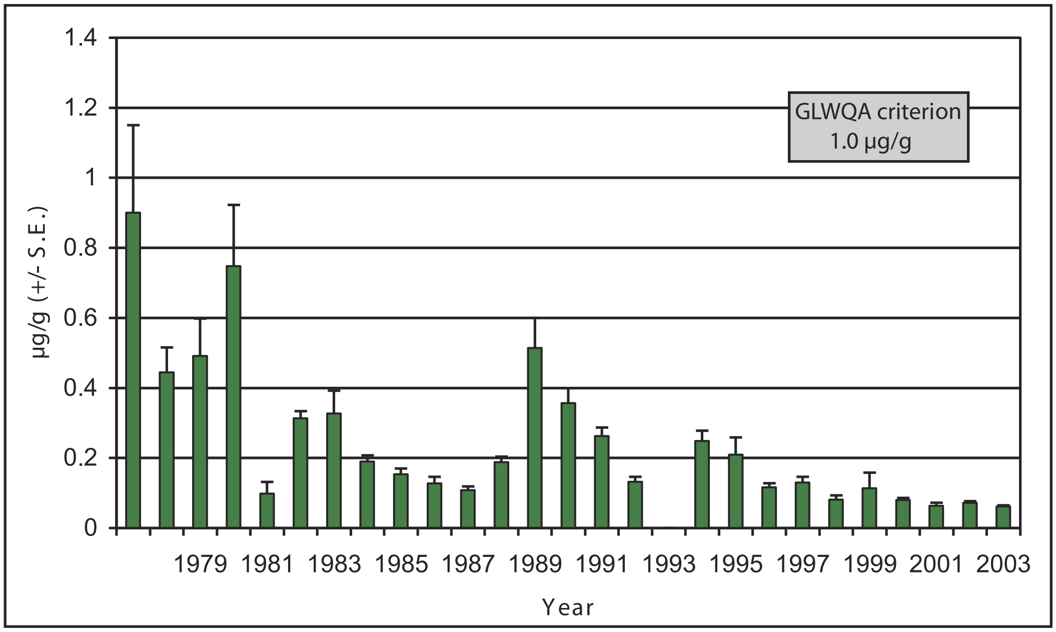
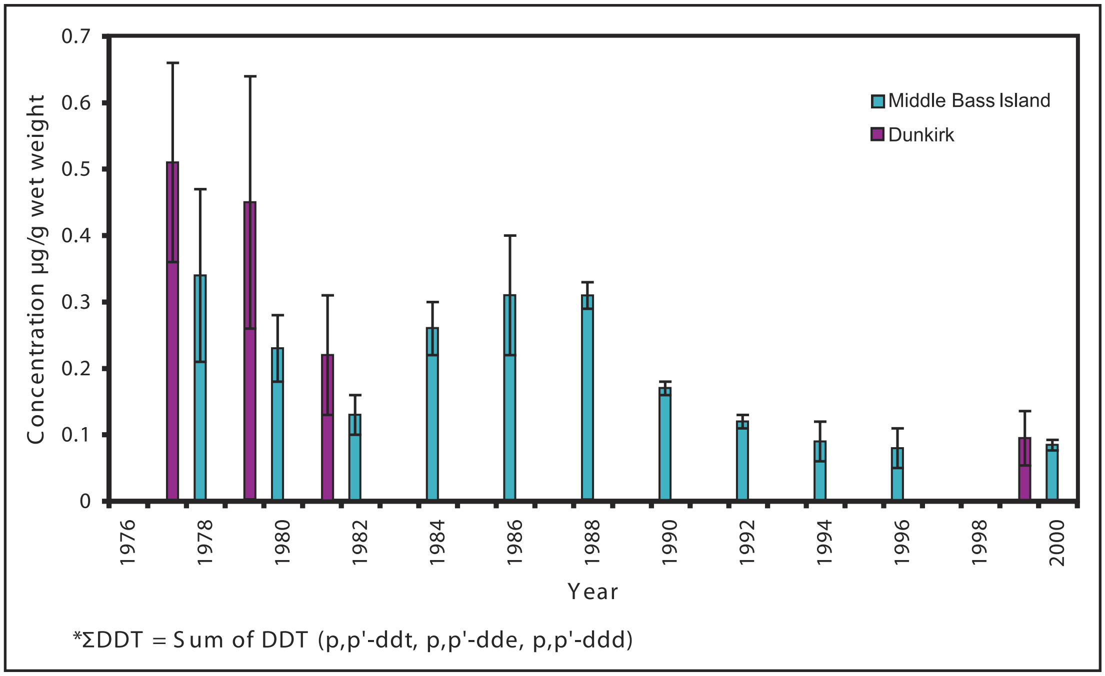


Figure 10:17: ΣDDT levels in whole Walleye (450 - 550 mm size) in Lake Erie, 1972 - 2000 (µg/g wet weight +/- 95% C.I., composite samples). (Source: EPA-GLNPO)



Total PCBs

The introduction of zebra mussels also affected contaminant trends of PCBs (Morrison et al 1998). GLNPO walleye demonstrate a period of increase in concentration from the late 1980s through the early 1990s, followed by a sharp decline in the early 1990s and a fairly stable concentration since then (Figure 10.18). DFO walleye demonstrated a similar period of annual increases from 1985 through 1993 associated principally with the proliferation of the zebra mussel population, followed by a decline in PCB concentration, and then remained relatively steady over the past four years through 2003 (Figure 10.19). DFO lake trout data show a decrease in concentration between 1990 and 2001, followed by a slight increase in concentration through to 2003 (Figure 10.20). DFO smelt data show a decline in concentration between 1990 and 2001, followed by a sharp increase in 2002 and an 80% decrease in 2003 (Figure 10.21). GLNPO and DFO recorded PCB concentrations in Lake Erie walleye and lake trout are above GLWQA criteria. DFO measured Lake Erie smelt PCB concentrations have exceeded GLWQA criteria, but there are also years where concentrations are below 0.1 µg/g.

Figure 10:18: Total PCB levels in whole Walleye (450 - 550 mm size range) in Lake Erie, 1972-2000 (µg/g wet weight +/- 95% C.I., composite samples). (Source: EPA-GLNPO)

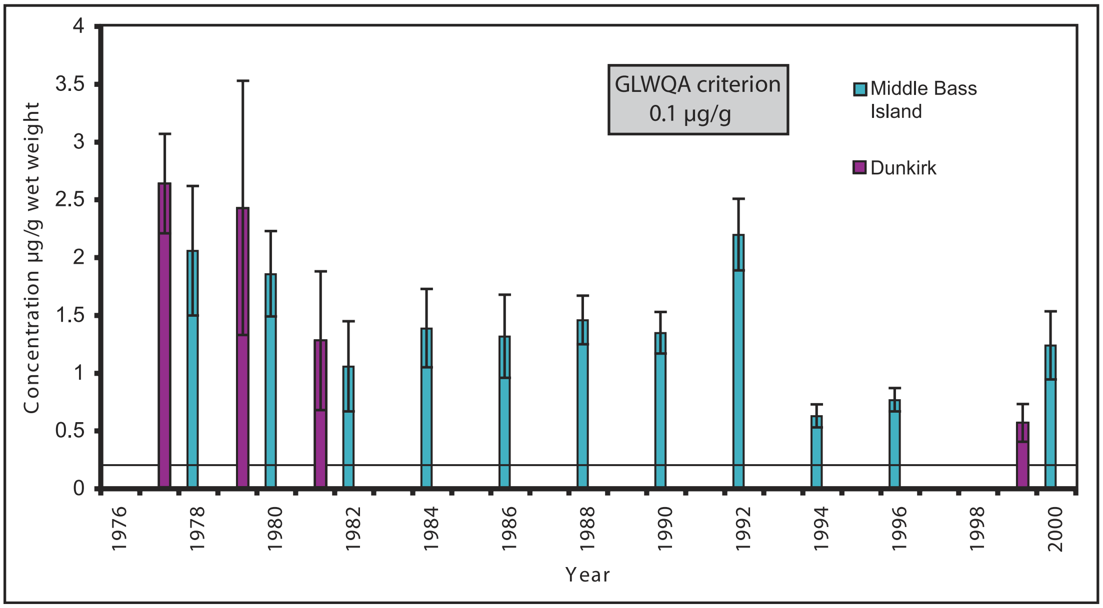


Figure 10:19: Total PCB Levels in Lake Erie Walleye 1977-2003 (µg/g +/-S.E. wet weight, whole fish, ages 4-6). (Source: DFO-GLLFAS unpublished data) GLWQA criterion is 0.10 µg/g.

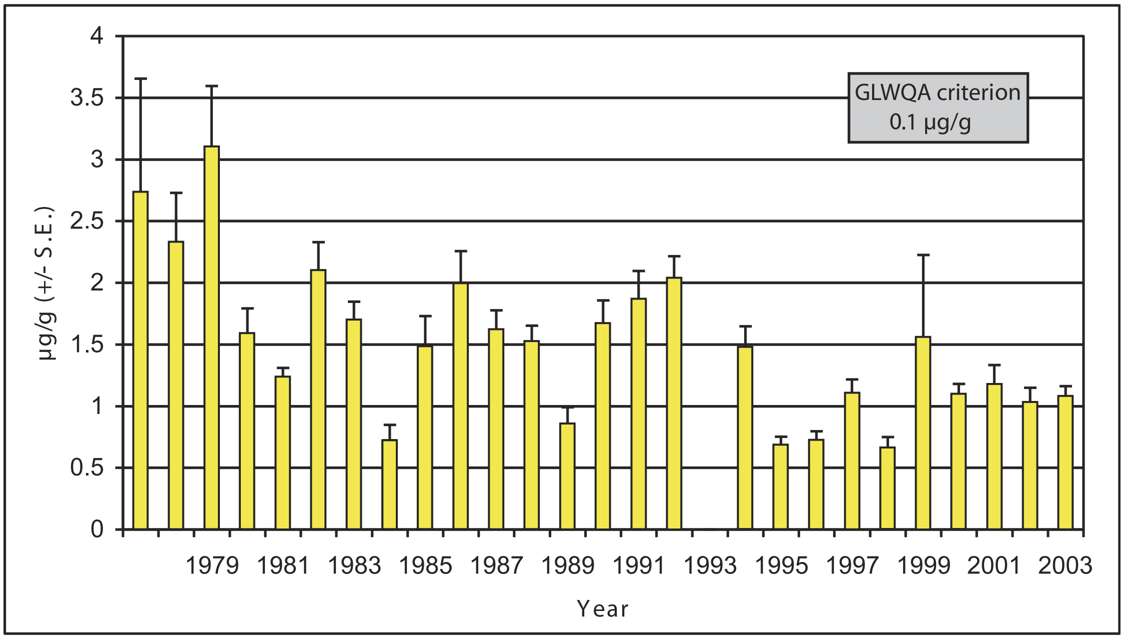


Figure 10:20: Total PCB levels in DFO collected Lake Erie Lake Trout 1985-2003 (µg/g +/- S.E. wet weight, whole fish ages 4-6). (Source: DFO-GLLFAS unpublished data) GLWQA criterion is 0.10 µg/g.

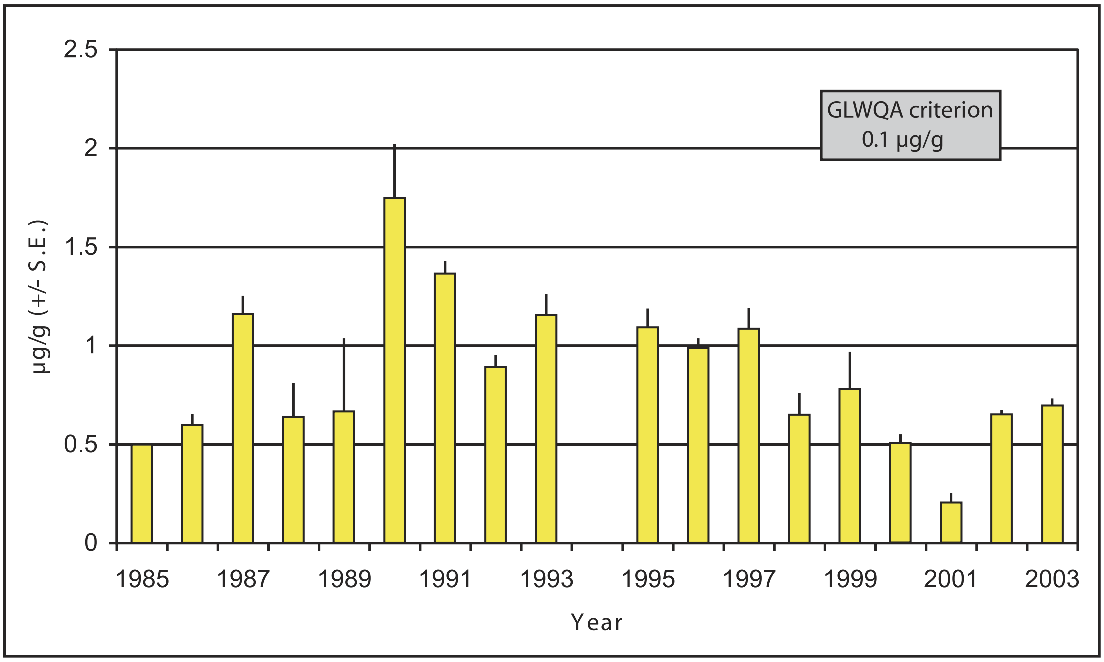
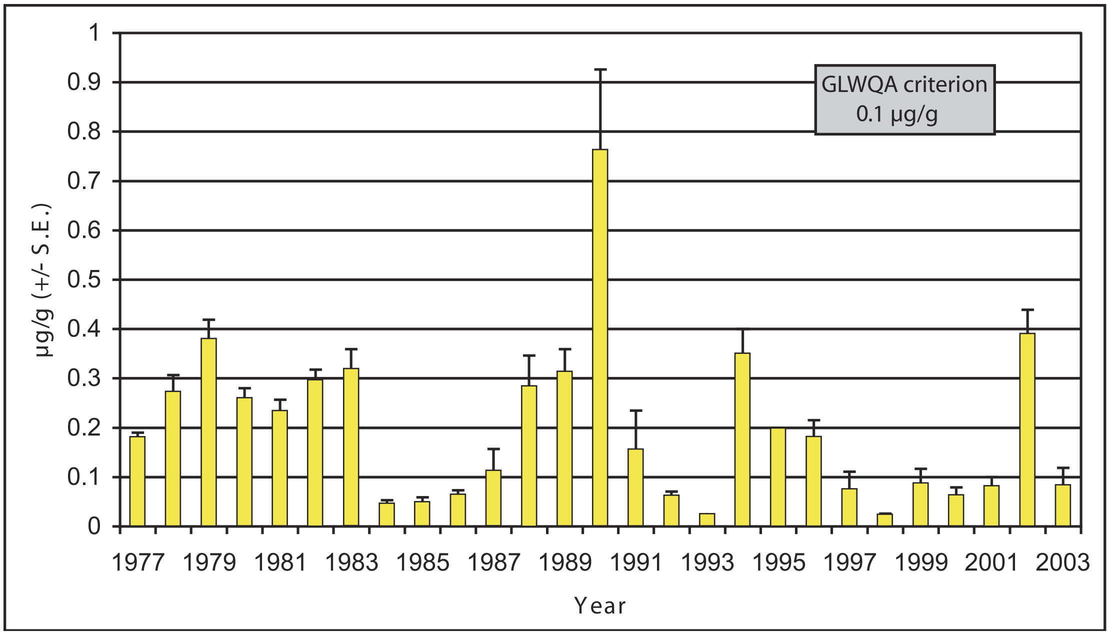


Figure 10:21: Total PCB levels in Lake Erie Rainbow Smelt 1977-2003 (µg/g +/- S.E. wet weight, whole fish). (Source: DFO-GLLFAS unpublished data) GLWQA criterion is 0.10 µg/g.



Mercury

After a period of rapid decline from 1977 through 1983, mercury concentrations in Lake Erie walleye have remained steady. After 1996, the frequency of annual measurements of mercury burdens in walleye by DFO was reduced. The mean of two recent measurements made in 1999 and 2003 was ~ 15% greater than the 5 year mean of the period 1992 through 1996 (Figure 10.22). DFO recorded mercury levels in walleye are less than the GLWQA criteria of 0.5µg/g. DFO smelt data show that concentrations of mercury measured in samples collected in 2002 had the highest concentrations reported since the whole lake survey was initiated in 1977. Subsequently, the 2003 concentrations were the second lowest concentration reported since 1977. DFO recorded concentrations of Lake Erie smelt are below GLWQA criteria (Figure 10.23).

Figure 10:22: Total Mercury levels in Lake Erie Walleye 1977-2003 (µg/g +/-S.E. wet weight, whole fish ages 4-6). (Source: DFO-GLLFAS unpublished data) GLWQA criterion is 0.50 µg/g.

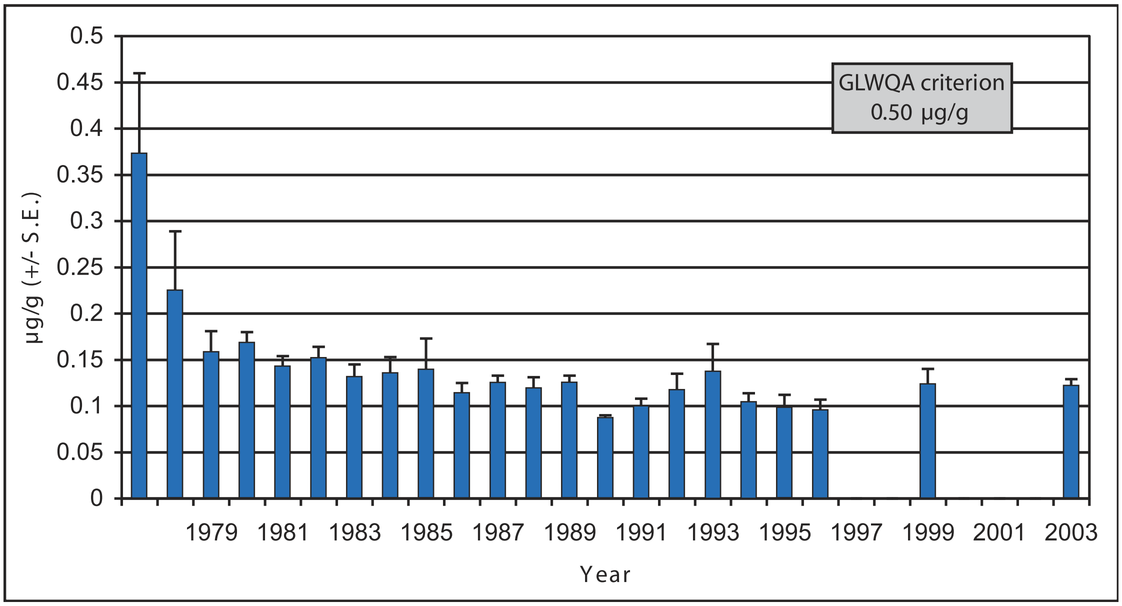
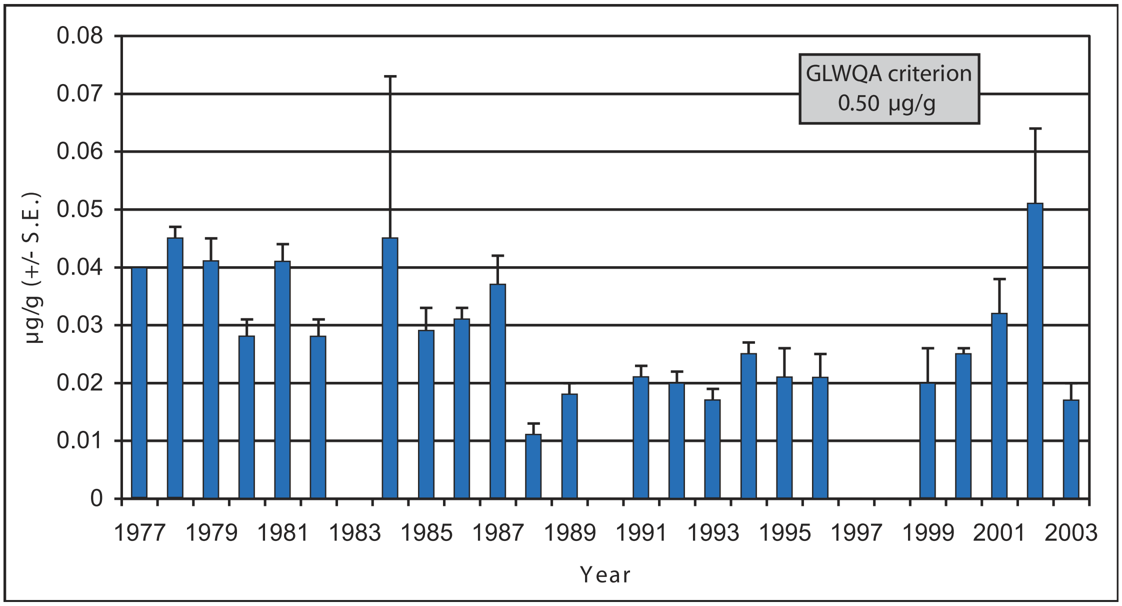


Figure 10:23 Total Mercury levels in Lake Erie Rainbow Smelt, 1977-2003 (µg/g +/-S.E. wet weight whole fish) (Source: DFO-GLLFAS unpublished data). GLWQA criteria is 0.50 µg/g.



Chlordane

Total chlordane is made up of five components: trans-nonachlor; cis-nonachlor; trans-chlordane; cis-chlordane; and oxychlordane. Trans-nonachlor is the most prevalent of the chlordane compounds. Lake Erie walleye were lower in trans-nonachlor concentrations than were lake trout in the other Great Lakes (Swackhamer 2004).

Dieldrin

Concentrations of dieldrin in Lake Erie appear to be declining. Concentrations of dieldrin in Lake Erie walleye were the lowest measured in all the Great Lakes.

10.9 International Field Years on Lake Erie (IFYLE) Program *(Prepared by Drs. Stuart A. Ludsin and Stephen B. Brandt, NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI)*

To improve the ability to provide reliable ecosystem forecasts for Lake Erie, the NOAA Great Lakes Environmental Research Laboratory initiated the integrated (multi-agency), multidisciplinary "International Field Years on Lake Erie" (IFYLE) Program in 2004. This program primarily seeks to: 1) quantify the spatial extent of hypoxia across the lake, and gather information that can help forecast its onset, duration, and extent; 2) assess the ecological consequences of hypoxia to the Lake Erie food web, including phytoplankton, bacteria, microzooplankton, mesozooplankton, and fish; and 3) identify factors that control the timing, extent, and duration of harmful algal bloom (HAB) (including toxin) formation in Lake Erie, as well as enhance our ability to use remote sensing as a tool to rapidly map HAB distributions in the lake.

The IFYLE Program has become the largest international, multidisciplinary research effort of its kind in Lake Erie's history, costing approximately $5 million and involving more than 40 scientists from NOAA, US and Canadian universities, and federal, state, and provincial agencies. Vessel support comes primarily from NOAA Ship Support, U.S.EPA-GLNPO, and NOAA-GLERL, whereas funds for external researchers were provided by the National Sea Grant College Program and the Ohio and New York Sea Grant College programs. Environment Canada deployed several moorings to collect physical data in collaboration with this program, while the US Army Corps of Engineers provided continuous dock space for NOAA vessels. In addition, the project has been offered in-kind support (e.g., historical data, technical assistance with aging fish, vessel support) from all of the state and provincial fishery management agencies on the lake, including the Ohio Department of Natural Resources, the New York State Department of Environmental Conservation, the Michigan Department of Natural Resources, the Pennsylvania Fish and Boat Commission, and the Ontario Ministry of Natural Resources.

The 2005 field program centered on determining the factors regulating the distribution of oxygen concentrations and HABs in Lake Erie and the consequences of low oxygen on the abundance, distribution, and condition of fish and their prey. The remainder of 2005 and all of 2006 will be devoted to sample processing, data analysis, testing and refining hypotheses, and building models that can be used for both understanding and forecasting purposes. During 2007, it is expected that another intensive field season will be conducted, with more focused sampling objectives.

For more information on the IFYLE program, see www.glerl.noaa.gov/ifyle/, or contact Dr Stuart A. Ludsin (Stuart.Ludsin@noaa.gov) and Dr Stephen B. Brandt (Stephen.B.Brandt@noaa.gov), co-coordinators of the IFYLE program.

10.10 Trends in Sediment and Nutrients in Major Lake Erie Tributaries, 1975-2004 *(Prepared by R. Peter Richards, National Center for Water Quality Research (NCWQR), Heidelberg College, Tiffin, Ohio)*

In the last decade or so, in-lake concentrations of phosphorus have been on the increase, though the trend is not statistically significant. Hypoxia in the central basin appears to be more extensive and occurring earlier in the summer. Extensive blooms of *Microcystis* and other undesirable algae have been observed in some recent years that are comparable to those of the 1970s. These signs all suggest that Lake Erie is out of trophic balance once again.

Most hypotheses that attempt to explain these observations implicate zebra and quagga mussels in processes that enhance in-lake recycling of nutrients or shunt them from nearshore to offshore or from the western basin to the central basin. However, during the last decade, increasing concentrations and loads of sediment and nutrients have been observed at many of the NCWQR tributary monitoring sites. This section documents these trends. We are unable to assess their importance relative to in-lake processes, but any efforts to understand the renewed problems in the lake must take these trends into account as well.

Photo: Jeff Schmaltz, MODIS Rapid Response Team, NASA/GSFC, April 6, 2004

Data and Approaches

The NCWQR maintains automated sampling stations on the Grand, Cuyahoga, Sandusky, and Maumee Rivers in Ohio, and on the River Raisin in Michigan. The data presented here deals only with the Ohio tributaries, but results for the River Raisin are similar. On each river, the sampling station is located at a USGS flow gauging station as far downstream as possible while remaining upstream of seiche-induced flow reversals. Samples are collected three times per day. All three samples are analyzed during periods of high flow, and one sample per day is analyzed at other times. This program produces 400-450 samples per station per year. Samples are analyzed for sediment, nutrients, and major ions, and a subset is analyzed for currently used pesticides and metals. Relevant information about each station is presented in Table 10.5. Further information about the tributary monitoring program and its results can be found at www.heidelberg.edu/WQL/publish.html#reports.

Table 10.5: Station Locations for NCWQR Sampling Sites

Station and USGS Number	Location	Drainage area (square miles)	First year of operation	Total number of samples
Raisin 04176500	Above Monroe, MI	1042	1982	7051
Maumee 04193500	Waterville, OH	6330	1975	12,965
Sandusky 04198000	Above Fremont, OH	1253	1969	13,863
Cuyahoga 04208000	Independence, OH	708	1981	10,331
Grand 04212100	Painesville, OH	686	1988	6686

For trend analysis, raw data were converted to daily values by calculating a flow-weighted mean concentration for each day with more than one sample. Concentrations were converted to daily loads by multiplying them by the daily average flow reported by USGS, and expressed as metric tons per day. No attempt was made to fill in values for days on which no samples were obtained.

Trends are displayed as LOWESS (Locally Weighted Scatterplot Smoother) smooths of the raw data. In all cases a 20% bin width was used. The position of the smoothed trend at any point in time is computed using the 10% of the data immediately before that point in time, and the 10% of the data immediately after it, with the greatest weight given to the points that are closest in time. This technique allows a general trend to be extracted from very "noisy" data, without imposing severe restrictions such as the assumption that the trend must be a straight line.

For statistical assessment, trends were computed with a two-slope analysis of covariance (ANCOVA) model that divides the data into two periods, before and after January 1, 1995. A separate linear trend is computed for each period. This approach was chosen because an initial trend analysis reported results for the period 1975-1995, and because many parameters show a strong change in trend occurring somewhere about 1995. The model uses log-transformed flow and concentration, and sine and cosine terms in time are used to model seasonality. Results are reported as percent change in average daily load per decade.

Results

LOWESS trends are depicted for the four Ohio tributaries in Figures 10.24-10.27. The graphs cover the period of record (through the end of the 2004 water year) except that the Sandusky River plots begin at the beginning of the 1975 water year. The trends for the Grand River are shorter, for example, because the station did not begin operation until 1988.

Values are reported as loads in metric tons per day. In comparing the results for different stations, remember that the Maumee watershed is much larger than the rest, and consequently the loads will also be larger, other things being equal. Also note that the plots cover the range of the trend values, but do not extend to zero. Plotting the trends in this fashion makes them appear more dramatic than they would if they were plotted on a scale that extended to zero. Conversely, if plotted in the context of the total range of the data, the trends would appear quite modest. However, the impact of these changes on the lake is more a function of gradual changes over time than of day-to-day fluctuations, and the curves as displayed portray these gradual changes well.

Flow

Since loads are determined by the product of concentration and flow, a trend in loads may reflect a trend in concentration, a trend in flow, or a trend in both. Conceivably, an upward trend in concentration could be negated by a downward trend in discharge, resulting in no trend in loads. The flow trends (Figure 10.24) are provided primarily as background for use in interpreting the load trends. However, substantial trends in flow are a cause for concern in and of themselves, particularly for possible negative impacts on riverine ecosystems. A striking aspect of the flow trends is the strong increase in flow in all tributaries except the Maumee, beginning about 2000. This increase in flow is reflected in increased loads as well. The Maumee also shows increased flow, but it appears to begin somewhat earlier and the increase is not as pronounced.

Suspended Sediment

Suspended sediment (SS) is important as a pollutant in its own right, particularly in the bays, harbors and nearshore zone of the lake. SS is also important because many pollutants of concern are carried attached to it. This is particularly true of phosphorus and some forms of nitrogen (as well as metals and many organics, which are beyond the scope of this report). Studying trends in SS (Figure 10.25) may help identify causes of trends in other parameters. Sediment load trends are obviously influenced by flow trends, though the patterns differ in detail, reflecting the fact that there are changes in concentration as well. The Maumee shows a strong and persistent downward trend in sediment loads. Given the dominance of the Maumee as a source of sediment and nutrients to western Lake Erie, this is an important and gratifying trend.

Total Phosphorus

Total Phosphorus (TP) is the nutrient parameter chosen as the indicator of trophic status for the remediation of Lake Erie. As such it is a very important parameter from a management standpoint. Most of the TP in transit in Lake Erie tributaries is attached to sediment particles, but the percent of TP that is particulate varies from one tributary to another and from season to season, and has changed significantly over time. The load trends for TP (Figure 10.26) are similar to those for SS, especially for the Sandusky and Grand Rivers. Increasing loads since approximately 2000 characterize all tributaries except the Maumee, which, while not increasing, is no longer showing declining trends.

Dissolved Reactive Phosphorus

While total phosphorus is the parameter by which Lake Erie eutrophication is managed, dissolved reactive phosphorus (DRP) is also of great importance because it is highly bioavailable. Thus increases in DRP can have disproportionately large impacts on the Lake Erie ecosystem. Increasing trends in DRP loads (Figure 10.27) in the recent past characterize all four tributaries, and are particularly pronounced for the Sandusky and Grand. These increasing trends follow a period of strong decreasing trends for all tributaries except the Grand, for which the period of record is perhaps too short to have captured such a trend. The onset of increasing trends is earlier than for the other parameters discussed, and occurs sometime between 1990 and 1995, depending on the tributary. While these load trends are influenced by trends in flow, there are also strong parallel trends in concentration, indicating other causes for these trends than just changes in flow.

Results of ANCOVA Analysis

Linear trends for the periods of time before and after 1995 are presented in Table 10.6. These results clearly show that the overall pattern of change before 1995 was one of improvement (i.e. reduced loads), while the overall pattern since 1995 is one of deterioration (i.e. increased loads). For technical reasons, assessments of the level of statistical significance of these trends are not presented. Other forms of analysis indicate that most of the trends are statistically significant, particularly those that exceed 10% per decade. In evaluating these results, which often involve reversals of trends, it is well to remember the asymmetry of percentages of change: If one starts with a value of 100, and reduces it to 40, that is a 60% decrease, but the return to the original value of 100 from 40 represents a 250% increase. The net change is not 190% but 0%.

Table 10.6: Percent Change per Decade in Daily Loads, Before and After 1995

Parameter	Maumee		Sandusky		Cuyahoga		Grand	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Flow	13	36	8	56	-17	41	-8	19
Suspended Sediment	8	-5	-6	34	-32	202	-93	5
Total Phosphorus	-11	29	-20	79	-69	61	-76	32
Dissolved Reactive Phosphorus	-50	199	-55	341	-88	212	-59	226

Two things stand out in these results. One is the uniformly large reversals in trends of DRP; in general the loads at the end of 2004 are nearly as high as or higher than they were at the beginning of the period of record. The other is the consistency of trend reversals. For the three water quality parameters (excluding flow), 11 of 12 trends pre-1995 were downward, but 11 of 12 trends post-1995 are upward.

Causes

Little definitive can be said about causes at this point. Certainly increased flows have contributed to increased loads. But concentration trends show similar patterns of recent increase. There are a large number of plausible causes, including: demographic changes, especially exurbanization; increased numbers of farm animals increasingly confined to small areas; and possible retrenchment of conservation tillage or reduced effectiveness of conservation tillage because of nutrient concentration at the surface. Data on many possible causes is difficult or impossible to obtain. Evaluation of causes may require development of highly sophisticated models that link watersheds with tributary systems, the lake, and its biota.

Figure 10.24: Trends in flow, 1975-2004. Units for flow are cubic feet per second.

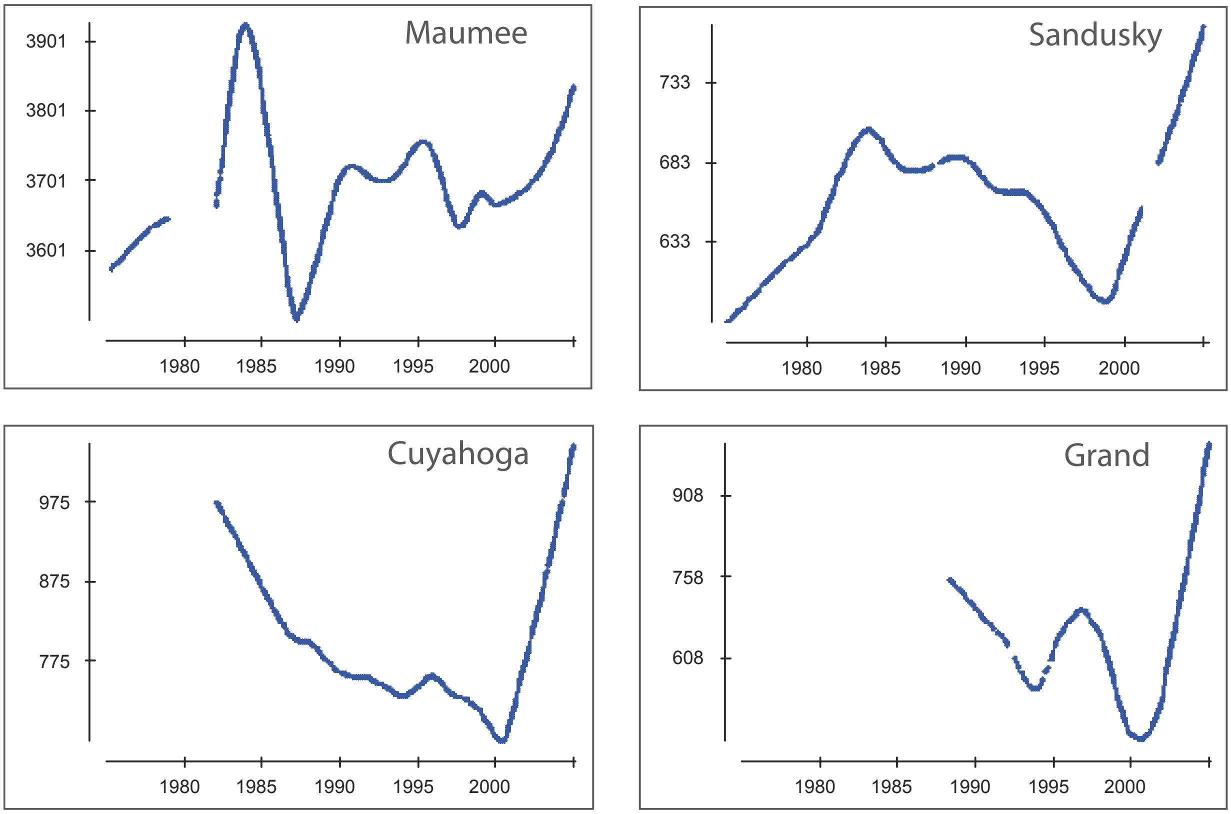


Figure 10.25: Trends in suspended solids, 1975-2004. Units for SS are metric tons per day.

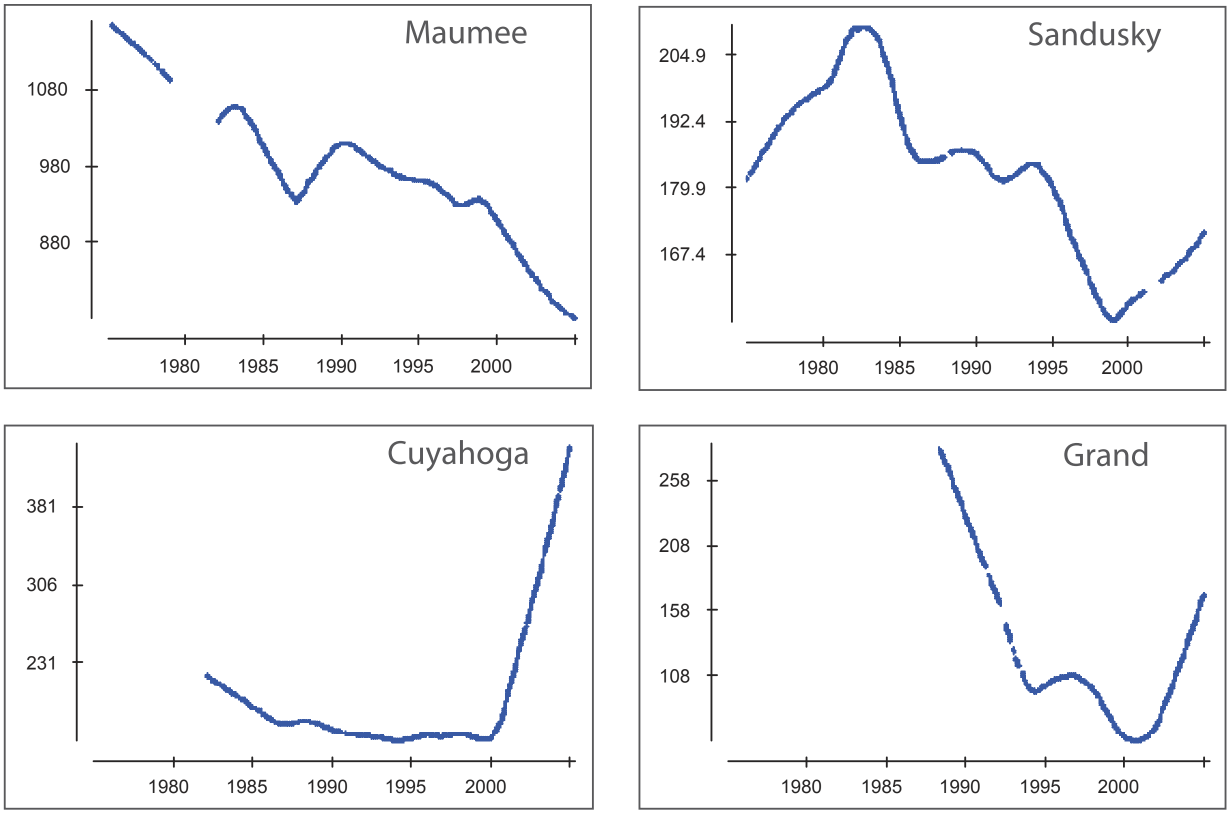


Figure 10.26: Trends in total phosphorus, 1975-2004. Units for TP are metric tons per day.

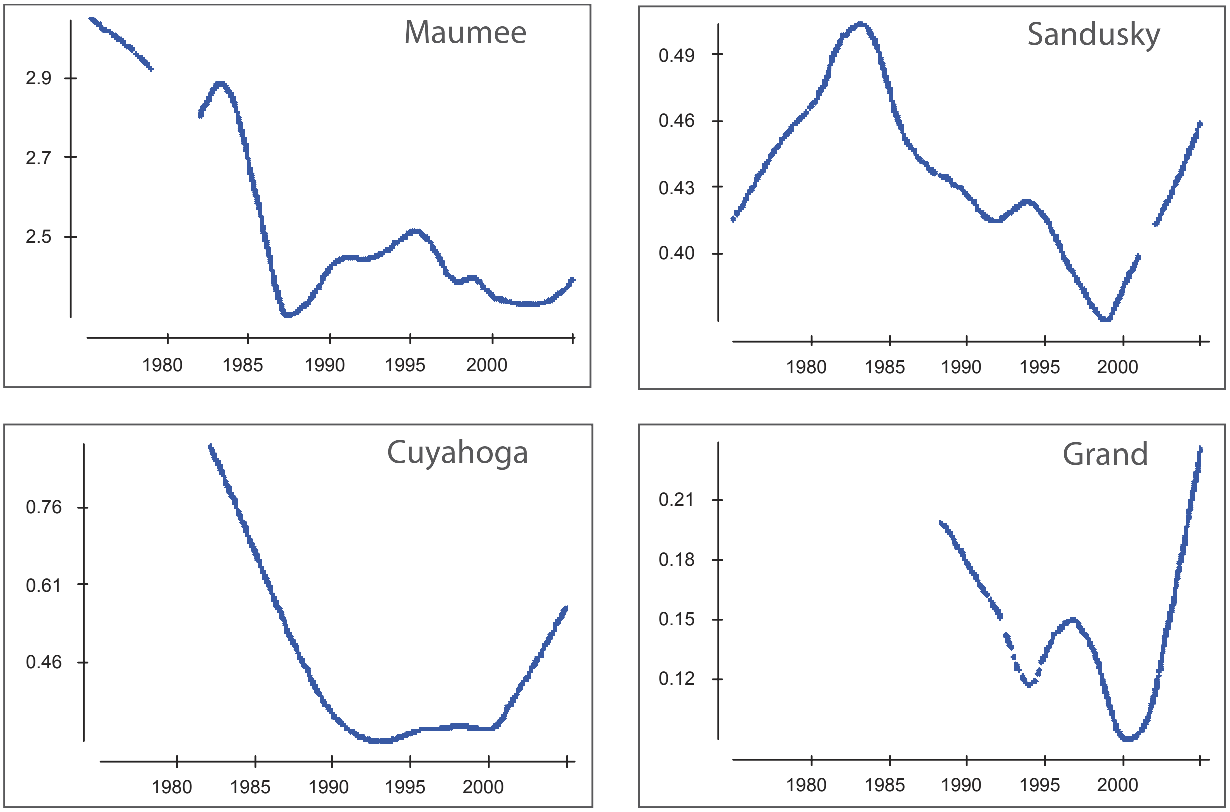
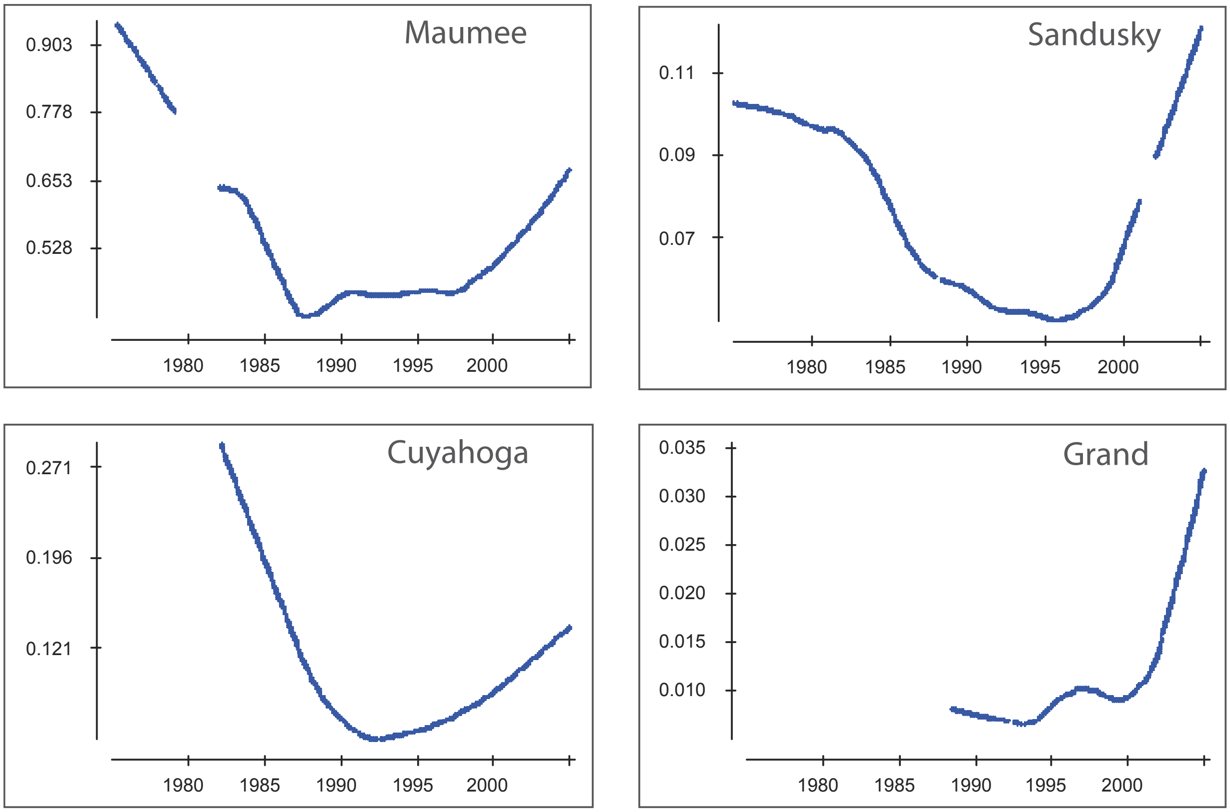


Figure 10.27: Trends in dissolved reactive phosphorus, 1975-2004. Units for DRP are metric tons per day.



10.11 References

Cook, P.M., Robbins, J.A., Endicott, D.D., Lodge, K.B., Guiney, P.D., Walker, M.K, Zabel, E.W., and Peterson, R.E. 2003. Effects of Aryl Hydrocarbon Receptor-Mediated Early Life Stage Toxicity on Lake Trout Populations in Lake Ontario during the 20th Century. Environmental Science and Technology. 37(17):3878-3884.

Environment Canada. 2001. Bald eagle populations in the Great Lakes region. Great Lakes Fact Sheet. Canadian Wildlife Service. www.on.ec.gc.ca.

Martin, J.W., D. M. Whittle, D.C.G. Muir & S.A. Mabury. 2004. Perfluoroalkyl Contaminants in the Lake Ontario Food Web. Environ. Sci. Technol. V 38, No 20 (5379-5385)

Morrison, H.A., F.A.P.C. Gobas, R. Lazar, D.M. Whittle and G.D. Haffner. 1998. Projected Changes to the Trophodynamics of PCBs in the Western Lake Erie Ecosystem Attributed to the Presence of Zebra Mussels (Dreisennia polymorpha). Environ. Sci. Tech. 32, 3862-3867.

Morrison, H.A., D.M. Whittle and G.D. Haffner. 2000. The Relative Importance of Species Invasions and Sediment Disturbance in Regulating Chemical Dynamics in Western Lake Erie. Ecological Modelling 125: 279-294.

Roe, A.S., A.H. Birrenkott, M.C. Shieldcastle, W.W. Bowerman, K.A. Grasman, and J.M. Wing. 2004. Developing the bald eagle as a Lake Erie biosentinal: Contaminant trends in nestling bald eagles in Ohio. Final report for Ohio Lake Erie Protection Fund grant.

Stock, N.L., Bonin J., Whittle, D.M., Muir, D.C.G., and Mabury, S.A.. 2003. Perfluoronated Acids in the Great Lakes. SETAC Europe 13th Annual Meeting, Hamburg, Germany.

Swackhamer, D. 2004. Trends in Great Lakes Fish Contaminants. Final report to GLNPO. http://www.epa.gov/glnpo/glindicators/fishtoxics/GLFMP%20Final%20Report%201999-2000%20v4.pdf

Tomy, G.T., Budakowski, W., Halldorson T., Whittle, D.M., Keir, M., Marvin, C., MacInnis, G., and Alaee, M. 2004. Biomagnification of α and γ-Hexabomocyclododecane in a Lake Ontario Food Web. Environ. Sci. Technol. 38:2298-2303.

United States and Canada. 1987. Great Lakes Water Quality Agreement of 1978, as amended by Protocol signed November 18, 1987. Ottawa and Washington www.ijc.org/rel/agree/quality.html

Whittam, B. 2000. Southern Ontario bald eagle monitoring project. 2000 Report. Bird Studies Canada.

Whittle, D.M., MacEachen, D.C., Sergeant, D.B., Keir, M.J., and M.D. Moles. Food Web Biomagnification of Brominated Diphenyl Ethers in Two Great Lakes Fish Communities, pp 83-86. 3rd International Workshop on Brominated Flame Retardants, Toronto, Ontario.

Section 11: Significant Ongoing and Emerging Issues

Photo: U.S. Fish & Wildlife Service

11.1 Introduction

The dynamic nature of Lake Erie means that things change, often unpredictably. Section 2 describes how the issues of concern in the lake have changed over time. Some of the issues were resolved through management actions over a short period of time, while others required long-term and ongoing management plans. Some goals, such as phosphorus concentrations in the lake, were considered achieved until zebra mussels invaded and concentrations began fluctuating again. The invasion of a host of new non-native species has created much alteration in the biological community. The ecosystem management objectives for Lake Erie attempt to set goals for management actions in the areas of land use, nutrient management, contaminants, resource use and non-native invasive species. It may be necessary to continually revisit these goals as new unexpected situations arise. This section provides some insight into programs and problems that are currently important in the lake, as well as those that may be emerging as important future issues. The adaptive management approach of the LaMP process accepts the fact that change is inevitable. The challenge to the LaMP is to keep abreast of lake conditions, identify and encourage research in areas needed to make the appropriate management decisions, and modify management goals and actions when needed.

11.2 2003 Update on Non-Native Invasive Species in Lake Erie *(Prepared by Lynda D. Corkum & Igor A. Grigorovich, University of Windsor)*

A detailed overview on the history of non-native invasive species in Lake Erie was presented in Section 11 of the Lake Erie LaMP 2000 document. An update of ongoing and emerging issues (including non-native invasive species) was presented in Section 10 of the 2002 Lake Erie LaMP report. This is the second update on the status of non-native invasive species (NIS) in Lake Erie. The material presented represents new information on NIS (and anticipated invasions) as well as historical information that was not presented in the previous reports.

Of the approximately 170 NIS in the Laurentian Great Lakes drainage basin (A. Ricciardi, McGill University, personal communication), there are about 132 NIS in the Lake Erie watershed, including: algae (20 species), submerged plants (8 species), marsh plants (39 species), trees/shrubs (5 species), disease pathogens (3 species), molluscs (12 species), oligochaetes (9 species), crustaceans (9 species), other invertebrates (4 species), and fishes (23 species) (Leach 2001). The number of NIS is a conservative estimate because small organisms, or those that are difficult to classify, are typically less well studied.

The increase in NIS during the 20th century is attributed to the shift from solid to water ballast in cargo ships and to the opening of the St. Lawrence Seaway in 1959 (Mills et al. 1993). Ballast water discharge from ships has been the primary vector for NIS entering the Great Lakes (Mills et al. 1993). Despite voluntary (1989-1992) or mandatory (1993 onward, United States Coast Guard, 1993) compliance with the ballast water exchange program, the rate of NIS introductions from 1989 to 1999 has tripled compared to the previous three decades (Grigorovich et al. 2003a). Unfortunately, vessels with cargo designated with "no ballast on board" (NOBOB) status are not subject to regulations even though these vessels carry residual ballast water and associated organisms (Bailey et al. 2003). Between 1981 and 2000, about 72% of NOBOB vessels made their first stop at Lake Erie ports where they unloaded cargo and took on Great Lakes water to compensate for the loss in cargo weight (Grigorovich et al. 2003a). The mixing of water with residual sediment could result in increased invasions. The Lake Huron-Lake Erie corridor has been identified as one of the four invasion "hotspots" along with the Lake Erie-Lake Ontario corridor, the Lake Superior-Huron corridor and the western end of Lake Superior (Grigorovich et al. 2003a). The hotspots represent less than 5.6% of the total Great Lakes water surface area, but account for more than half of the NIS documented since 1959 (Grigorovich et al. 2003a).

Lake Erie ranks second to Lake Ontario (31 sites) of all Great Lakes for first records of NIS. There have been 22 sites in the open waters of Lake Erie where non-native invasive aquatic animals and protists were first reported (Table 11.1). Explanations for the large number of NIS reported in the lower Great Lakes may be due to the intensive sampling in the region, similar physical/chemical characteristics between donor and recipient regions, lake productivity, and facilitation of invasion by previously established invaders. Given the many species introductions into Lake Erie by human activities, natural barriers to dispersion and gene flow among the Great Lakes have been essentially eliminated (de LaFontaine and Costan 2002).

There have been reports of new invaders in Lake Erie. Protozoans (Rhizopoda), *Psammonobiotus communis* (two sites east of Wheatley to Rondeau on the north shore of Lake Erie) and *P. dziwnowii* (eastern Lake Erie), were reported in a 2002 survey of Lake Erie (Nicholls and MacIsaac 2004). It is likely that these euryhaline species entered the Great Lakes through ballast water. *Psammonobiotus communis* is pandemic, whereas *P. dziwnowii* was found only on the Polish coast of the Baltic Sea before it was reported in Great Lakes waters. A new species, *Corythionella golemanskyi*, also has been described. These three species have been described from several Great Lake locations where they occur in beach sand. It is likely that these species became established long ago, but investigators simply had not looked for them (Nicholls and MacIsaac 2004).

Lake Erie proper has 34 non-native invasive fish species and new species are likely to enter the lake from the Mississippi drainage basin and from adjacent lakes. The common carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*) were likely the first introduced fishes into the Great Lakes. Carp were intentionally introduced into the Great Lakes in 1879 as a food fish (Emery 1985). By the 1890s, carp were "very abundant in the Maumee River at Toledo, Ohio and in the west end of Lake Erie" (Kirsch 1895). Carp are a nuisance because they degrade habitat for native fish and waterfowl and feed on eggs of other fish (Fuller et al. 1999). Goldfish, often cultured for bait and used in the aquarium trade, may have been the first foreign fish to be introduced to North America (Courtenay et al. 1984). Back-crossing and hybridization between goldfish and carp is common. In Lake Erie, hybrids may be more abundant than either parental species (Trautman 1981). Western Lake Erie has some of the largest populations of goldfish in the continental United States (Fuller et al. 1999), particularly in the shallower waters of the basin with dense vegetation and in the low-gradient tributaries of the lake (Trautman 1981).

Table 11.1: Non-native Metazoans and Protists First Established in Lake Erie Since the 1800s (Grigorovich et al. 2003b). Taxonomic groups are listed from most ancient to most advanced; species are listed in alphabetical order within each taxonomic group. The Protista were reported in hosts of other animals.

Number	Taxonomic Group	Species Name	Year of 1st Discovery	Location
1	Protista	*Acineta nitocrae*	1997	Lake Erie
2	Protista	*Glugea hertwigi*	1960	Lake Erie
3	Protista	*Myxosoma cerebralis*	1968	Ohio drainage, Lake Erie
4	Cnidaria	*Cordylophora caspia*	1956	Lake Erie
5	Cnidaria	*Craspedacusta sowerbyi*	1933	Lake Erie
6	Bryozoa	*Lophopodella carteri*	1934	Lake Erie
7	Mollusca	*Cipangopaludina japonica*	1940	Lake Erie
8	Mollusca	*Corbicula fluminea*	1980	Lake Erie
9	Mollusca	*Dreissena bugensis*	1989	Port Colborne, Lake Erie
10	Mollusca	*Pisidium moitessierianum*	1895	Lake Erie
11	Annelida	*Barbidrilus paucisetus*	2001	Lake Erie
12	Annelida	*Potamothrix vejdovskyi*	1965	Lake Erie
13	Annelida	*Pristina acuminata*	1977	Lake Erie
14	Annelida	*Pristina longisoma*	2001	Lake Erie
15	Annelida	*Psammoryctides barbatus*	2001	Lake Erie
16	Crustacea	*Daphnia galeata*	1980s	Lake Erie
17	Crustacea	*Daphnia lumholtzi*	1999	Lake Erie
18	Crustacea	*Echinogammarus ischnus*	1994	Lake Erie
19	Crustacea	*Eurytemora affinis*	1991	Lake Erie
20	Pisces	*Lepomis humilis*	1929	Lake Erie
21	Pisces	*Oncorhynchus kisutch*	1933	Lake Erie
22	Pisces	*Phenacobius mirabilis*	1950	Ohio drainage, Lake Erie

There have been a few instances of accidental occurrences of other species of Asian carp in Lake Erie. In 2000, there were unusual sightings of the Chinese bighead carp, *Hypophthalmichthys nobilis*. On October 16, 2000, the third specimen ever of Chinese bighead carp was caught in a trap net on the west side of Point Pelee in the western basin of Lake Erie (T. Johnson, Ontario Ministry of Natural Resources, Wheatley, personal communication). The fish is native to eastern China and introduced into the United States in 1973. The 2000 sighting was probably the result of a fish escape from aquaculture ponds (T. Johnson, personal communication). In October 30, 2003, a grass carp (*Ctenopharyngodon idella*) was caught at the mouth of the Don River, Lake Ontario (Beth MacKay, OMNR, personal communication). It is believed that this record was an isolated occurrence and that there are no established populations of grass carp in the Great Lakes. Earlier (1985), a grass carp was reported from Lake Erie.

Southern U.S. fish farmers introduced several species of Asian carp to control vegetation (grass carp), algal blooms (bighead and silver carp) and snails (black carp) in aquaculture facilities. The grass carp, bighead carp, silver carp (*Hypophathlmichthys molitrix*) and the black carp (*Mylopharyngodon piceus*) have been released and/or have escaped into the wild. All of these species are large fish with adults ranging from 20 to 40 kg. Both bighead carp and silver carp are moving upstream in the Mississippi and Illinois Rivers towards the Great Lakes basin (Taylor et al. 2003). These species of Asian carp will likely spread into the Great Lakes if mechanisms are not established to stop their upstream spread. Bighead and silver carp are a threat to Great Lakes fish because they filter and consume plankton. The competition threat from these species exists for all fish because each fish species consumes plankton early in development. There is also anticipated competition between the Asian carp and adults of commercially important lake whitefish, *Coregonus clupeaformis,* and bloaters, *Coregonus hoyi*, that rely on plankton.

An electric barrier (energized in April 2002) on the Des Plaines River, Illinois, was designed to impede the exchange of organisms between the Great Lakes and Mississippi basins. In addition to the electric barrier, other guidance systems (Sound Projection Array, SPA) are being tested to deter the species of Asian carp from upstream movement. The SPA uses an air bubble curtain that creates a wall of sound that deters fish away from designated regions. This technique combined with a graduated electric field barrier was effective in laboratory studies in repelling 83% of fish that attempted to cross the barrier (Taylor et al. 2003). Field studies on the effectiveness of the electric barrier in preventing fish passage are on-going.

Kolar and Lodge (2002) used a quantitative model to predict potential invasive fishes and their impact in the Laurentian Great Lakes. If introduced, five Ponto-Caspian fishes will likely become established in the Great Lakes and are expected to spread quickly (Table 11.2). Intentional introductions result from aquaculture, sport fishing, pet trade and bait fishes. Three species (Eurasian minnow, European perch and monkey goby) are currently in the water garden or aquarium trade in Europe.

Table 11.2: Ponto-Caspian Fishes and Pet, Sport, Aquaculture and Bait Species Predicted to Become Established in the Great Lakes if Introduced (Kolar and Lodge 2002). Family names are listed from most ancient to most derived groups.

Family	Scientific name	Common name	Unintentional Introductions	Intentional Introductions
Clupeidae	*Clupeonella cultriventris*	Tyulka	X	
Cyprinidae	*Phoxinus phoxinus*	Eurasian minnow	X	
Cyprinidontidae	*Aphanius boyeri*	Black Sea silverside	X	
Percidae	*Perca fluviatilis*	European perch		X
Gobiidae	*Neogobius fluviatilis*	Monkey goby		X

The non-native invasive round goby fish has continued to expand its range in the Great Lakes basin. The fish entered western Lake Erie in 1993 and, since 1999, has occupied all three basins of the lake. There were an estimated 14.5 billion round gobies in western Lake Erie in 2001 (Johnson et al. 2003). Videography was the most effective tool (in comparison with trawls or traps) used to determine the density of this bottom-dwelling species (Johnson et al. 2003). Lee (2003) determined that the round goby population in western Lake Erie consumes more than 2.6×10^4 tonnes of benthic prey each year, 17% of which is represented by invasive dreissenids. Clearly, zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*) have facilitated the establishment of the round goby.

Efforts in Great Lakes jurisdictions are being made (and more are needed) to control the entry of non-native invasive species introduced through ballast water, canals and recreational boating (Vásárhelyi and Thomas 2003). However, there are relatively few practices in place to control established invasive species without affecting non-target species or resulting in collateral environmental damage. Because attempts to eliminate a NIS throughout an ecosystem are not possible, control programs are typically species and site specific. “Introductions, like extinctions, are forever” (Marsden 1993).

One recent example to develop an effective control measure focuses on reducing the reproductive success of the round goby. Laboratory findings support the hypothesis that mature female round gobies actively respond by moving to sex attractants released by conspecific males (Corkum et al. 2003). It is expected that the application of this research will lead to the development of a control strategy using natural pheromones to disrupt reproductive behaviours of the invasive round goby. Because juvenile and adult round gobies feed on eggs of several native fishes (lake trout, Chotkowski and Marsden 1999; lake sturgeon, Nichols et al. 2003; and smallmouth bass, Steinhart et al. 2004), there is great value in reducing the reproductive success of this invasive predator. The ultimate goal is to develop a pheromone trap that targets round gobies (and no other species) to be deployed at known spawning locations of native fishes where round gobies co-occur and are known to prey on eggs of native fishes (Corkum et al. 2003).

Although the focus of NIS in Lake Erie is on aquatic invasive species, a metallic wood-boring beetle (Family, Buprestidae), known as the emerald ash borer (*Agrilus planipennis*), has damaged millions of ash trees in the western Lake Erie drainage basin (Michigan, Department of Agriculture Fact Sheet). The exotic beetle, native to Asia, was first discovered in southeast Michigan in 2002. It has now spread to northwest and central Ohio. Many infested trees in these areas have been cut down and burned. The beetle also has been reported in Windsor, Ontario, and is expanding throughout Essex County into southwestern Ontario. A quarantine is established to help prevent the movement of ash trees and ash products outside the infested regions. Evidence of infestation is the characteristic D-shaped beetle exit holes on the branches and trunks on ash trees. Although little is known about the control or management of this pest, research projects are currently underway.

Once NIS colonize a waterbody, become established, disperse and ultimately affect either native species or habitat, the management options to control the species become more limited at each step in the process (Kolar and Lodge 2002). In November 2001, Environment Canada and the Ontario Ministry of Natural Resources organized a national workshop on invasive alien species to identify issues in the management of invasive species. Since then, the federal, provincial and territorial Ministers for Wildlife, Forests, and Fisheries and Aquaculture approved a "blueprint" for a National Plan and requested the establishment of four working groups including: 1) invasive aquatic species; 2) terrestrial animals; 3) terrestrial plants; and, 4) leadership and co-ordination. A discussion document was prepared, providing a hierarchical approach to respond to invasive alien species that prioritizes: 1) the prevention of new invasions; 2) the early detection of new invaders; 3) rapid response to new invaders; and, 4) the management of established and spreading invaders (containment, eradication, and control) (Anonymous 2003) (Beth MacKay, OMNR, personal communication).

Public awareness efforts are essential in reporting, preventing and slowing the spread of established non-native invading species. The Great Lakes Sea Grant Network in the United States and the Ontario Federation of Anglers and Hunters in collaboration with the Ontario Ministry of Natural Resources have established effective Invasive Species Awareness programs (Dextrase 2002). There is a Great Lakes Panel on Aquatic Nuisance Species to develop and co-ordinate invasive species in the Great Lakes basin. For information, contact the Great Lakes Commission web site (www.glc.org), Sea Grant State Offices or the Ontario Federation of Anglers and Hunters Invasive Species Hotline at 1-800-563-7711. It is the collaborative and co-operative efforts among the public, government agencies, non-government agencies, academic institutions and industry that will result in effective management of non-native invasive species (Dextrase 2002).


Photo: Eric Engbretson, U.S. Fish & Wildlife Service

11.3 Nutrients and the Food Web: a Summary of the Lake Erie Trophic Status Study *(Presented at the Lake Erie Millennium Network Third Biennial Conference 2003, prepared by Jan Ciborowski, University of Windsor)*

Photo: Upper Thames River Conservation Authority

Long-term records relating to Lake Erie's nutrient status suggest a process of reduced nutrient status. U.S. EPA's water quality data show a downward trend of eutrophy (the Carlson Trophic State Index) for the period 1983-2000. Furthermore, concentrations of total phosphorus in the water, averaged over the whole year have been falling by about 0.2 mg/m^3/yr. However, the amounts of nutrients present in the water in early spring have continued to rise, extending to eight years a trend that was first seen in 1995. Much of the among-year variation in the amount of phosphorus entering the lake over the last few years is due to the intensity and timing of storms, which cause flooding and erosion, rather than to municipal inputs. Data from the last several years indicate that more phosphorus is leaving Lake Erie in the waters of the Niagara River than is entering the Lake from the major tributaries.

The period of water turbidity associated with spring is persisting longer than formerly. The planktonic algal cells are smaller than they were in the 1980s, and there seem to be more algae during the spring than in the late 1990s. However, zooplankton are not more abundant than previously. Over the period 1991-2000, the biological demand for oxygen in the bottom waters of Lake Erie's central basin has not changed, when averaged over the whole year. Biological oxygen demand of the sediments seems to increase over the course of the summer.

In summertime, light is penetrating deeper into the water - algae are now growing (and producing oxygen) in the deep layers of the central basin and on the western and central basin lake bottoms. Extensive layers of the filamentous alga, *Cladophora* are common along rocky shorelines around the Lake. There is also more bacterial activity deep in the water, but there are very few planktonic algae in the shallow water near shore, where zebra mussels are most abundant. There is only limited evidence that the scarcity of planktonic algae is due to nutrient limitation, either in the spring, or later in summer. Microbes in the water are more likely to be limited by the availability of carbon than by either phosphorus or nitrogen. Studies to determine if the scarcity of trace metals such as iron, copper or zinc may be limiting algal production have been inconclusive. The picoplankton are most responsive to experimental additions of these metals.

Populations of dreissenid (zebra and quagga) mussels and *Hexagenia* mayflies are steady or declining. The development of thick mats of algae along shorelines, especially in the eastern and central basins, reduces the living space available for dreissenid mussels. Zebra mussels have all but disappeared from eastern and central basins, being supplanted by quagga mussels. Overall mussel densities seem to be lower than in recent previous years, possibly because there are so many gobies now in the lake. The diversity and abundance of invertebrate animals, especially mayflies and net-spinning caddisflies in the wave-washed zone of the shoreline, have dropped markedly since the last time they were surveyed in the 1970s.

The goby population in Lake Erie is large, but the numbers are quite a bit lower than they were two years ago. Most of the gobies occur in rocky and sandy areas closer to shore in all three basins. Gobies will likely become an acceptable source of food for walleye. Gobies are now common in the diets of almost all of the Lake Erie sports fish.

Evidence seems to suggest that we are seeing new pathways of internal cycling of nutrients, likely caused by the activities of dreissenids, which may be altering the size structure and dynamics of particles in Lake Erie. However, the consequences of physical (weather-related) influences cannot be ruled out as an accompanying explanation for the apparent increasing frequency and extent of central basin anoxia events. The persistent periods of spring turbidity may be due to the effects of heavy fall and winter storms, which contribute more sediment for a given amount of precipitation than summer storms. Also, cold water is more viscous than warm water, causing particles to settle more slowly. Spring water temperatures in 2002 and 2003 have been among the coldest on record, perhaps partly accounting for the greater concentrations of spring turbidity and possibly associated nutrients.

11.4 Climate, Water Levels and Habitats (Based on contributions by Jan Ciborowski, University of Windsor and Jeff Tyson, Ohio Department of Natural Resources)

There is now stronger evidence than ever of human-induced climate change. For example, the average water temperature of Lake Erie has risen by 0.4 degrees C over the past 18 years (Burns et al. in press). Between 2004 and 2090, our climate is expected to continue to become warmer. This will result in significant reductions in lake level, exposing new shorelines and creating tremendous opportunities for large-scale restoration of highly valued habitats.

It is natural for Lake Erie's water level to fluctuate seasonally, annually and over decades. Research has documented 30 and 150-year cycles in Lake Erie water levels with water levels fluctuating over a 2-meter (~6 ft.) range in the past 85 years, from low water of 173.2 m (568.18 ft.) in 1936 to high water of 175.1 m (574.28 ft.) in 1986. Given the low relief topography associated with Lake Erie, Lake St. Clair and the Niagara River, significant shoreline areas typically cover and uncover with decadal changes in water level. Short-term seiche effects on Lake Erie are also particularly pronounced at either end of the lake when strong winds from the southwest or northeast persist for several days. Associated with these changing lake levels is a moving Aquatic Terrestrial Transition Zone (ATTZ) that needs to be allowed to migrate freely landward or lakeward to continue to provide the appropriate ecological role in the Lake Erie ecosystem.

There are many positive effects of seasonally, annually, and decadally flooded terrestrial and nearshore habitats including: increased habitat diversity (Junk et al. 1989), spawning and nursery areas, phytoplankton production (Gladden and Smock 1990) and inputs of nutrients and carbon into the aquatic food web (Junk et al. 1989). However, significant shoreline modifications have degraded nearshore habitats and reduced the ability of Lake Erie to support healthy aquatic communities. Currently greater than 90% of the southern shoreline of the western basin is hydro-modified (through armoring), with very little nearshore vegetation or "shallow-water" habitat (<0.5 m) present.

In the offshore areas, oscillations and/or changes in Lake Erie water levels directly impact the thickness of the hypolimnion which in turn has a profound impact on the amount of deep, oxygenated, cold water habitat that is available to the cold water aquatic community in the eastern and central basins. These changes in water levels could also have a dramatic effect on the duration of the anoxic/hypoxic "dead" zone in the central basin of the lake, further impacting habitat.

Climate change experts predict that Lake Erie water levels may become as much as 85 cm (33.5 in) lower over the next 70 years, and its surface area may shrink by as much as 15%. Total amounts of precipitation may not change on an annual basis, but storms will become less frequent and more intense. Strong winds will also become more common. The changes in timing and amounts of precipitation and runoff will require different strategies for water management.

Three other human activities - water diversion, consumptive use and water level regulation - also have the potential to affect lake levels. Diversion refers to transfer of water from one watershed to another. Consumptive use refers to water that is withdrawn for use and not returned. Most consumptive use in the Great Lakes is caused by evaporation from power plant cooling systems.

Studies by the IJC in 1982 concluded that current diversions and consumptive uses in the Great Lakes are not having significant impacts because the volume of water in the lakes is so large. They caution however, that if consumptive uses continue to increase at historical rates, outflows to the St. Lawrence River could be reduced by as much as 8% by 2030. The Great Lakes states, Ontario and Quebec are currently working on Annex 1 to the 1985 Great Lakes Charter to better manage future requests for diversions and water uses of Great Lakes waters.

Studies conducted by the IJC in 1964 and again in 1993 to assess the feasibility of regulating lake levels, concluded that the costs of the major engineering works required and the negative environmental impacts would exceed the benefits provided. The IJC recommended instead that comprehensive and coordinated land-use and shoreline management programs be put in place to reduce vulnerability to flood and erosion control damages.

New methods are being developed to monitor the condition of the land next to the lake and its likely effect on the nearshore water. GIS and the advent of more powerful computer technology are improving our ability to map and interpret the characteristics of the water and lake bottom, and to understand their importance to the biota. A project is underway to produce a single, integrated map of habitat types and conditions for the entire Lake Erie watershed. The success of this initiative will ultimately depend on continuing participation of the Lake Erie Millennium Network agencies through data sharing and support for funding requests. Such information is crucial if we are to anticipate the changes in habitat structure and their consequences for both land and water management in the Lake Erie basin.

All the physical events discussed will have noticeable effects on Lake Erie shoreline habitats in the future. As lake levels decline and the armoring uncovers, the potential for nearshore emergent and submergent vegetation to recolonize these areas is high. The potential for restoration of other natural shoreline processes, such as littoral substrate drift, also exists with the re-establishment of a more natural shoreline. We should anticipate the changes in habitat structure that will accompany these changes and their consequences for both coastal and lakewide processes. Opportunities also exist to reduce the potential for flood and erosion control damages. These circumstances represent a unique opportunity to restore nearshore habitats and processes and protect shorelines on a lake basin scale, if the newly exposed lands are managed appropriately.

11.5 Double-Crested Cormorants in the Great Lakes
(Prepared by Mike Bur, USGS)

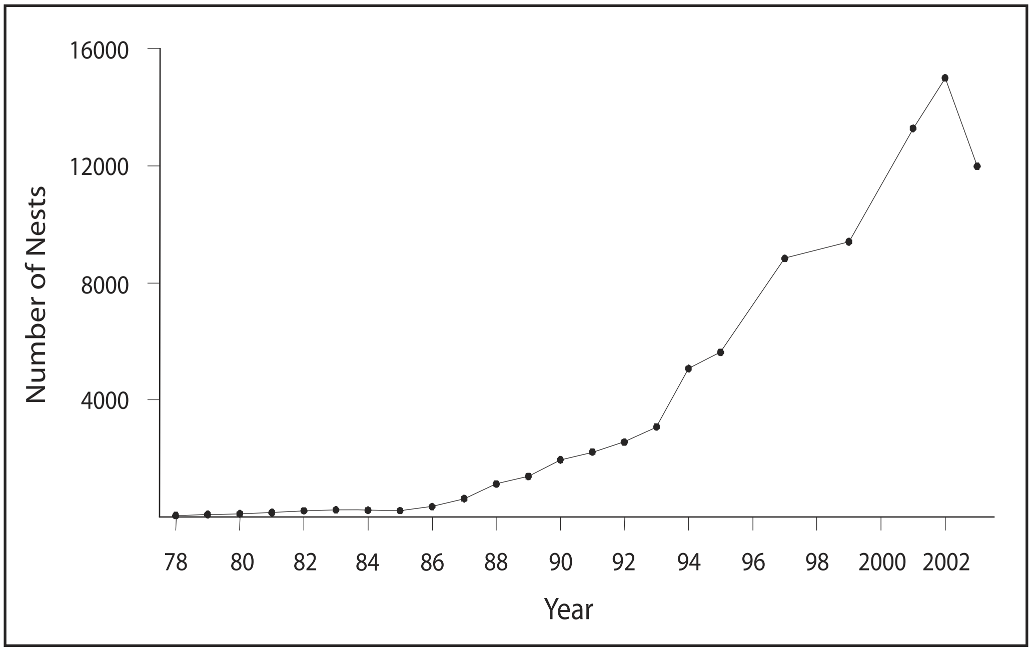
Double-crested cormorants are colonial waterbirds that breed in large colonies, often mixed with other species, and can nest on the ground or in trees. They have an extensive range in North America, occurring throughout the interior as well as on both coasts. For the contiguous United States as a whole, the breeding population increased at an average rate of 6.1% per year from 1966-1994, and now stands at approximately 372,000 breeding pairs. The total number of breeding and non-breeding birds is estimated at nearly two million birds. Resident populations in the southcentral United States disappeared or declined throughout the middle

Photo: Lee Karney, U.S. Fish & Wildlife Service of the 20th century. The interior and California populations declined from 1950 to 1970 (Hatch 1995). However, by the late 1980s most populations were increasing (Jackson and Jackson 1995, Carter et al. 1995, Krohn et al. 1995).

The first report of cormorant nesting on the Great Lakes occurred between 1913 and 1920, and by 1950 the breeding population was at 900 pairs (Weseloh et al. 1995). Human persecution and environmental contaminants led to the virtual extinction of cormorants on the Great Lakes by the early 1970s. From 1970 to 1991 the Great Lakes cormorant population increased from 89 nests to more than 38,000 nests. The population has increased at an annual rate of 23 percent from 1990 to 1994 (Tyson et al. 1999). Major factors leading to an increase in the Great Lakes population were reduced contaminants and persecution plus an abundance of prey fish (Weseloh et al. 1995, Blokpoel and Tessier 1996). By 2003 there were more than 100,000 nesting pairs in the Great Lakes. On Lake Erie there has been a dramatic increase in the number of nests. In 1978, there were 58 nests, and by 2002 there were nearly 15,000 nests. In 2003, the number of nests dropped to just below 12,000, a decline of over 20% (Figure 11.1).

With the burgeoning cormorant population there has been an increase in conflicts with commercial and sport fisheries in the Great Lakes. The common opinion of many fishers is that cormorants have a negative impact on the fish communities. After increasing concerns arose, diet and related studies were conducted to identify impacts of cormorant feeding on the Great Lakes fisheries. The effect of cormorants on fish populations in open waters is less clear than at aquaculture facilities. Studies conducted worldwide have repeatedly shown that while cormorants can, and often do, take fish species that are valued in commercial and sport fisheries, those species usually comprise a very small proportion of the birds' diet. One study found that in Lake Erie the number of these fish (i.e. yellow perch, smallmouth bass, and walleye) consumed by cormorants was less than 5 percent of the total consumed (Bur et al. 1999). Other studies suggest that cormorants have the ability to deplete fish populations in localized areas (Burnett 2001; Lantry et al. 1999; and Rudstam et al. 2004). In Canada, double-crested cormorants are managed under the authority of the Provincial agencies. The Ontario Ministry of Natural Resources is currently conducting a research program to assess the effects of cormorants on fish stocks, and is working with U.S. State and Federal agencies to manage cormorants where necessary and appropriate.

Figure 11.1: Total number of double-crested cormorant nests on Lake Erie



A major concern is the adverse impacts cormorants have on vegetation in nesting colonies and roosting areas. These birds often inadvertently kill trees and vegetation with their feces. Some of these areas include stands of uncommon or rare species, such as the

Kentucky coffee tree, *Gymnocladus dioicus,* remaining on most of the Lake Erie islands. Vegetation alteration may affect the ecological balance of an area and, to a lesser extent, possibly lower property, recreational, and aesthetic values. Cormorants can affect other colonial waterbirds at mixed and breeding colonies directly by physical displacement and indirectly by altering the vegetation (Trapp et al. 1999). Lake Erie's West Sister Island has the largest colonial waterbird colony in the Great Lakes.

Since 1972, depredation permits allowing the taking of double-crested cormorants have been authorized on a case-by-case basis, usually when negative impacts on aquaculture operations and habitat have been demonstrated. Most permits were for birds causing depredation problems at aquaculture operations. The U.S. Department of Agriculture's Wildlife Services Division is responsible for documenting economic losses.

The persistence of conflicts associated with double-crested cormorants, widespread public and agency dissatisfaction with the status quo, and the desire to develop a more consistent and effective management strategy for double-crested cormorants has steered the U.S. Fish & Wildlife Service to the decision to prepare a national cormorant management plan for the contiguous United States. The purpose of the draft Environmental Impact Statement on double-crested cormorants is threefold: to reduce resource conflicts associated with double-crested cormorants in the contiguous United States; to enhance the flexibility of natural resource agencies in dealing with double-crested cormorant-related resource conflicts; and to ensure the conservation of healthy, viable double-crested cormorant populations.

Under the EIS preferred alternative, a new "public resource depredation order" will authorize States, Tribes, and U.S. Department of Agriculture's Wildlife Services to manage and control double-crested cormorants to protect public resources (fish, wildlife, plants, and habitats). The order allows control techniques to include egg oiling, egg and nest destruction, cervical dislocation, shooting, and CO2 asphyxiation. The order applies to 24 states including the Lake Erie states: Michigan, Ohio and New York. Agencies acting under the order must have landowner permission, may not adversely affect other migratory bird species or threatened and endangered species, and must satisfy annual reporting and evaluation requirements. The USFWS will ensure the long-term conservation of cormorant populations through annual assessment of agency reports and regular population monitoring.

Conservation measures will also protect fish, other birds, vegetation, federally listed threatened and endangered species, water quality, human health, economic impacts, fish hatcheries, property losses, and aesthetic values.

11.6 Status of the Fish Community *(Prepared by Jeff Tyson, Ohio Department of Natural Resources and Phil Ryan, Ontario Ministry of Natural Resources)*

Lake Erie's fisheries differ strongly from the other Great Lakes because they rely predominantly upon natural reproduction of native species within the lake and its tributaries. Rehabilitation of these environments is critical to restoration of biological integrity of the Lake Erie ecosystem. The Lake Erie Committee of the Great Lakes Fishery Commission has established goals and objectives to define rehabilitation, and to recognize that the Lakewide Management Plan is vital to recovery of ecosystem integrity. A healthy fish community will be a measure of restoration of that integrity.

Walleye is a critically important species to the ecology and fisheries of Lake Erie. As a top predator with broad distribution, this species is expected to bring more stability to the fish community. Information from tagging and genetics studies shows that the population is composed of several distinct stocks. There are three major spawning sites in western Lake Erie: the Maumee River, Sandusky River, and the island shoals. There are also three major spawning areas in eastern Lake Erie: the New York shoreline, Grand River (ON) and nearby shoals. The success of Lake Erie's walleye in reproduction depends on environmental conditions at these sites (e.g. total suspended solids in the Maumee and Grand Rivers) and other river and lake habitats that support the early life history of this species.

The walleye population built up in the 1980s with the help of two very strong year classes, but began a long-term decline in the 1990s. The Lake Erie Committee of the Great

Lakes Fishery Commission recognized the need to protect the reproductive potential of the population under the "Coordinated Percid Management Strategy." Harvest levels were reduced from 2001 to 2003, by Ontario, Michigan, New York, Ohio and Pennsylvania. Conservative harvest levels were established earlier in eastern Lake Erie (East Basin Rehabilitation Plan 2000-04) in Ontario's jurisdiction. A strong year class of walleye in 2003 has provided potential to bring the population back up.

The yellow perch population in Lake Erie also declined in the 1990s, but its recovery began with the strong 1996-year class in the western and central basins. A strong year class in 1998 has supported recovery in eastern Lake Erie.

Lake trout is an important top predator for the cold-water fish community in eastern Lake Erie. The species is being re-established by stocking. Survival of stocked fish was depressed in the 1990s, but has improved in recent years. Like walleye, lake whitefish had a strong year-class in 2003. Lake herring have been rare in Lake Erie since the early 1960s. While they are still considered to be rare, there are signs that a slow increase in the population is occurring. The current state of Lake Erie's fisheries and strategies for coordinated management will be presented in a "State of the Lake" report at the annual meeting of the Lake Erie Committee in Grand Island, NY in late March 2004.

Photo: Mike Weimer, U.S. Fish & Wildlife Service

11.7 Cyanobacteria *(Prepared by Julie Letterhos, Ohio EPA and Jan Ciborowski, University of Windsor)*

Blooms of blue-green algae (Cyanobacteria) are again becoming noticeable at certain places and times. Some species produce chemical (microcystins) that are potent toxins to humans and wildlife.

In the 1960s and 1970s blue-green algal blooms were commonplace in Lake Erie. Shorelines were often rimmed in aqua, and offshore waters were thick with algae in the warm calm months of August and September. As Lake Erie began to respond to the efforts of phosphorus reduction, and phosphorus levels dropped toward the limits established by the Great Lakes Water Quality Agreement, blue-green algal blooms began to decrease and then disappeared altogether. Quite suddenly and unexpectedly, cyanobacteria blooms recurred in the western basin in 1995. This time the blooms were dominated by *Microcystis aeruginosa,* a non-nitrogen-fixing species that produces the hepatotoxin microcystin. Past blue-green blooms were dominated by nitrogen-fixing species such as *Anabaena* and *Aphanizomenon*. It was suspected that the blooms were associated with dreissenids and potentially to a changing P/N ratio in the lake.

Blooms did not occur in 1996 or 1997, but did come back in 1998, 2001, 2002 and 2003. Blooms in 2003 were particularly heavy, not just in the western basin, but also in the central basin (Figure 11.2). The percent biomass of cyanobacteria is also increasing in the eastern

Figure 11.2: *Microcystis* Bloom in the Western Basin, August 18, 2003 (LANDSAT 7 Image)

basin. The recurrence of these algal blooms, along with the expanded areas of anoxia and hypoxia in the central basin, is suggesting a change in eutrophy in parts of the lake.

The "Lake Erie Trophic Study" and the "Lake Erie Plankton Abundance Study" are continuing to track the occurrence of *Microcystis* and other cyanobacteria as well as the status of the rest of the plankton community. There is a continuing need to do more research to understand the biology of these algae and the causes of their blooms. Samples collected in various open-water areas revealed a correlation between locations where blue-green algal pigments were most abundant and places where dreissenid mussels were abundant. There is a need to track the distribution and incidence of such blooms to improve our understanding of their risk to human and animal health.

11.8 *Cladophora* *(Prepared by Scott Higgins, University of Waterloo and Todd Howell, Ontario Ministry of the Environment)*

Cladophora glomerata is a filamentous green alga that grows attached to rocky lake bottoms and man-made structures in relatively well illuminated and alkaline waters. It was first identified in western Lake Erie in 1848. While *Cladophora* has a ubiquitous distribution throughout the Laurentian Great Lakes and associated tributaries, historical 'nuisance' growths were most often associated with excessive phosphorus loading. Where *Cladophora* growths are extensive the blooms are followed by a major sloughing, or dieback, event where filaments detach from the lake bottom and become free floating. Floating *Cladophora* mats tangle fishing nets, reducing their efficiency and increasing downtime for net-cleaning, and are a potential hazard for swimmers. Floating mats of *Cladophora* clog intake screens of municipal and industrial water intakes (IJC 2003; Kraft 1993; Michard 2005) increasing maintenance costs and sometimes resulting in costly short-term shut-downs. Shoreline accumulations of decaying *Cladophora* release obnoxious odors reducing shoreline property values, the aesthetic value of beaches and associated tourism. Recent research by Byappanahalli et al.

(2003) has documented high concentrations and survival rates (>6 months at 5ºC) of *E. coli* within shoreline accumulations of *Cladophora*. This research indicates that *Cladophora* mats are a potential source of *E. coli* to recreational waters, potentially confusing the use of *E. coli* as an indicator organism for pathogens derived from fecal material.

Cladophora filaments require hard surfaces such as rocky lake bottoms or man-made structures such as piers or break walls for attachment. Significant areas of shallow bedrock are restricted to the eastern basin, portions of the central basin's southern shoreline, and islands of the western basin. Man-made structures, however, are common to all basins.

The most recent systematic *Cladophora* surveys (1995-2002) by Howell (1998) and Higgins et al. (2005b) have been restricted to the eastern basin. Across the northern shoreline of the east basin dense *Cladophora* mats were found over 96% of available rocky lake bottom (Figure 11.3) and were not spatially limited to nutrient point sources such as the mouths of tributaries or sewage treatment outfalls. The standing biomass of *Cladophora* along this reach of shoreline was estimated to be 11,000 tonnes (dry weight). Shoreline accumulations of *Cladophora* (Figure 11.4) were common during July and August, causing noxious odors and prompting numerous complaints from local homeowners. Heavy shoreline accumulations of *Cladophora* were also noted along the southern shorelines of eastern Lake Erie in Dunkirk NY (Obert 2003).

In the central basin, persistent shoreline fouling by *Cladophora* has been noted in Rondeau Bay, Ontario (Shepley 1996), Cleveland, OH (Kraft 1993), and Pennsylvania shorelines (GLRR 2001). Data for other areas are not available. In the western basin *Cladophora* is currently found growing on bedrock areas surrounding offshore islands, and on man-made structures at the basin perimeter. However, to date no complaints from area residents have occurred regarding *Cladophora* fouling of shorelines in the western basin.

Figure 11.3: Underwater photograph of Lake Erie lake bottom overlain with *Cladophora*. Photo taken at Grant Point, 2 m depth, July 2003.

Figure 11.4: Shoreline fouling by *Cladophora* in eastern Lake Erie. Photo taken approximately 2 km south of Peacock Point, August 2001.

Figure 11.5: *In situ Cladophora* growth chamber with non-nutrient enriched agar.

Figure 11.6: *In situ Cladophora* growth chamber with phosphorus enriched agar.

The depth distribution of *Cladophora* is related to light availability, and the maximum depth of colonization in eastern Lake Erie was approximately 15m. The biomass of *Cladophora* at shallow depths (<5m) was found to be similar to levels during the 1960s and 1970s (median value 176 g DM m^{-2}). Depth integrated biomass likely increased due to increases in water clarity caused by zebra and quagga mussels. A *Cladophora* growth model (Canale and Auer 1982), originally developed on Lake Huron, was revised and validated in eastern Lake Erie (Higgins et al. 2005a). The model predicted that *Cladophora* growth was highly sensitive to soluble phosphorus concentrations during the spring and that reductions in ambient phosphorus concentrations would significantly reduce bloom occurrences. The modeling results were supported by direct evidence indicating that phosphorus concentrations within *Cladophora* tissues rapidly declined to critical levels by early summer. A preliminary phosphorus addition study using slow release nutrient agar also suggested *Cladophora* growth and biomass accrual were strongly P-limited (Figure 11.5, 11.6) (S. Higgins, University of Waterloo).

Previous studies by Lowe and Pillsbury (1995) documented increases in benthic algal growth, including *Cladophora*, over zebra mussel beds in Saginaw Bay of Lake Huron. Unfortunately, benthic algal surveys were not conducted over the colonization period in Lake Erie. Efforts are currently ongoing to use the *Cladophora* growth model to estimate the influence of zebra and quagga mussels on *Cladophora* resurgence in the east basin (S. Higgins, University of Waterloo) and to investigate the influence of tributaries on growth potential in eastern Lake Erie (S. Higgins, University of Waterloo; and Ontario Ministry of the Environment).

11.9 Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants in the Environment
(Prepared by Jacqueline Fisher, U.S. EPA for the Great Lakes Human Health Network)

Over the past few decades, an increasing concern has developed about the potential and inadvertent contamination of water resources from the production, use, and disposal of the numerous chemicals used to improve industrial, agricultural, and medical processes. Analgesics, anti-inflammatory drugs, birth control chemicals, Prozac-like drugs, and cholesterol-lowering drugs have all been found in the effluent from water treatment plants discharging into the Detroit River, although at low concentrations (Lake Erie Millennium Network 2003). Even some commonly used household chemicals have raised concerns. Increased knowledge of the toxicological behavior of these chemicals raises the need to determine any potentially adverse effects on human health and the environment. For many of these contaminants, public health experts do not fully understand the toxicological significance, particularly the effects of long-term exposure at low levels. Further study needs to be done to determine the transport of these chemicals at trace levels through the environment and to determine any resulting adverse human health effects.

The U.S. Geological Survey conducted the first nationwide reconnaissance of the occurrence of pharmaceuticals, hormones, and other organic wastewater contaminants (OWCs) in water resources in 1999 and 2000. Concentrations of 95 OWCs in water samples from a network of 139 streams across 30 states were measured using five newly developed analytical methods. The selection of sampling sites was biased toward streams susceptible to contamination (i.e. downstream of intense urbanization and livestock production). OWCs were prevalent during this study, being found in 80% of the streams sampled. The compounds detected represent a wide range of residential, industrial, and agricultural origins and uses with 82 of the 95 OWCs being found during this study. The most frequently detected compounds were coprostanol (fecal steroid), cholesterol (plant and animal steroid), *N*,*N*-diethyltoluamide (DEET insect repellant), caffeine (stimulant), triclosan (antimicrobial disinfectant), tri(2-chloroethyl)phosphate (fire retardant), and 4-nonylphenol (nonionic detergent metabolite). Measured concentrations for this study were generally low and rarely exceeded drinking water guidelines, drinking water health advisories, or aquatic life criteria. Many compounds, however, do not have such guidelines established.

The detection of multiple OWCs was common for this study, with a median of seven and as many as 38 OWCs being found in any given water sample. Little is known about the potential interactive effects (such as synergistic or antagonistic toxicity) that may occur from complex mixtures of OWCs in the environment. In addition, results of this study demonstrate the importance of obtaining data on metabolites to fully understand not only the fate and transport of OWCs in the hydrologic system but also their ultimate overall effect on human health and the environment. (http://toxics.usgs.gov/regional/emc_sourcewater.html)

11.10 Fish and Wildlife Deaths Due to Botulism Type E
(Prepared by Jeff Robinson, Canadian Wildlife Service)

Since 1999 there have been annual large scale die-off events of fish, fish-eating birds and mudpuppies (a native aquatic amphibian) observed in Lakes Erie, Huron and, in 2003, Lake Ontario. These events have occurred annually in Lake Erie and it is here where the largest toll of fish and wildlife has occurred. The type E botulism bacterium is believed to be the cause of the die-off events.

Type E botulism is caused by *Clostridium botulinum,* a bacterium that is native to North America. The bacterium is quite widespread in the soils and sediments around the Great Lakes. Movement of the bacterium through the food chain resulted in mortality events of fish-eating birds in the Great Lakes basin during the 1960s. Humans were affected by food poisoning from poorly handled fish or wildlife and improperly prepared canned products. In the past, it has rarely been known to kill large numbers of fish or birds. Previous events primarily affected loons and grebes on Lakes Huron and Michigan.

On Lake Erie, shoreline landowners have observed remarkable natural fish die-offs as a result of strong storm fronts moving over the lake in the late summer or early fall. The lake has been warming through the summer and sets up a layer of warm surface water and a much colder layer in the deeper water generally well offshore. As these storm events or strong cold fronts pass, there are often sustained strong winds from the north that push the warmer surface waters to the south shore and bring the much colder water from deeper parts of the lake into the nearshore zone on the north shore. This results in a drop of the ambient water temperature so quickly and so drastically that resident fish, unable to escape the sudden temperature change, tend to be disabled or die. These events are quite regular as weather patterns, shoreline configuration and nearshore morphology do not change much over time. These dead fish afford an easy meal for inexperienced juvenile gulls and bald eagles learning to forage on their own. Occurring at a critical time of dispersal of young birds, this phenomenon has likely gone on for centuries.

What has been rarely observed in the past is apparent botulism type E poisoning of hundreds, if not thousands of fish-eating birds as well as dead fish and mudpuppies washing ashore in unprecedented numbers during the late summer and early fall period. Fall and early winter events have been less of a perceived problem as the number of recreational users on the beaches at that time of year is much lower.

Outbreaks

The earliest known or suspected incidents of type E botulism poisoning on Lake Erie have occurred during June, involving mudpuppies and gulls. These June incidents generally involved a few gulls found dead or dying along beaches or several hundred dead mudpuppies washed ashore or floating in the eastern basin of Lake Erie.

Summer die-off events tend to affect resident fish and wildlife whereas late summer events (August and September) start to affect populations of wildlife migrating through the Great Lakes. The fish affected tend to be bottom dwelling, warm water species such as: the round goby, stonecat, sheepshead, smallmouth bass, rock bass and sturgeon. The birds affected in the die-offs include: ring-billed gull, herring gull, double crested cormorant, greater black-backed gull, Caspian tern, common tern and a few shorebird species. Most of the birds involved breed near the areas where they are found dead. However, end of August outbreak events have found cormorants, breeding as far away as Lake Huron and eastern Lake Ontario, dead on Lake Erie.

The Canadian Wildlife Service reported that the fish die-off of freshwater drum and round goby at Wheatley, Ontario on August 16, 2001 did not result in any unusual bird mortalities. However, after a similar die-off of fish near Port Dover, Ontario also on August 16, there were 38 dead birds, one mudpuppy, three shorebirds and a report of a sick great blue heron. On October 29, 2001, the Canadian Wildlife Service reported die-offs of the common loon, ring-billed gulls, red-breasted mergansers, gadwalls, and long-tailed ducks (old squaw) along the northeast shore of Lake Erie between Port Dover and Dunnville in Ontario. In addition, there were dead fish along the beach including round goby, carp, and catfish as well as a mudpuppy. Specimens were sent to the Canadian Cooperative Wildlife Health Centre at the University of Guelph for assessment.

Similar mortalities of fish and birds occurred along the New York shoreline of Lake Erie during the same period. Among fish found dead along the New York shoreline in September 2001, 81% were freshwater drum (Figure 11.7) with the remainder consisting of nine other species. Bird collections in fall 2000 revealed an estimated 5,000 to 6,000 birds died that year, with red-breasted merganser the most common species (Figure 11.8). Estimates of dead common loons in New York were over 500 birds in 2000, and over 1000 birds in 2001. In addition, seven dead lake sturgeon (a threatened species in New York) were found in 2000, while 27 individuals were collected in 2001.

During the months of November and December bird deaths generally occur after the passage of strong cold fronts that appear to be related to mixing of lake waters, movement of migrant birds into Lake Erie and movement of fish from the nearshore to deeper water off shore. Thousands of waterfowl and loons have been observed over the past four years dead due to apparent botulism type E poisoning.

Figure 11.7: Frequency of dead fish species observed along NY Lake Erie beaches, September 2001

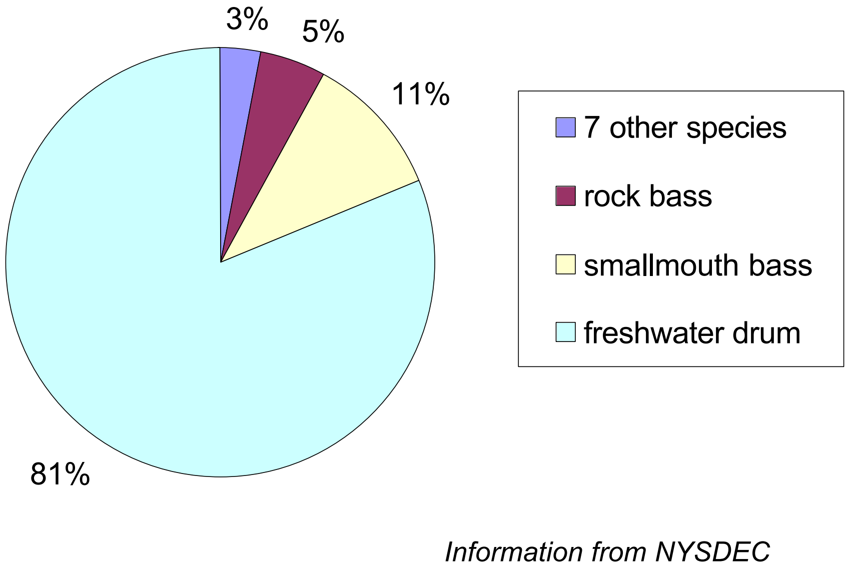
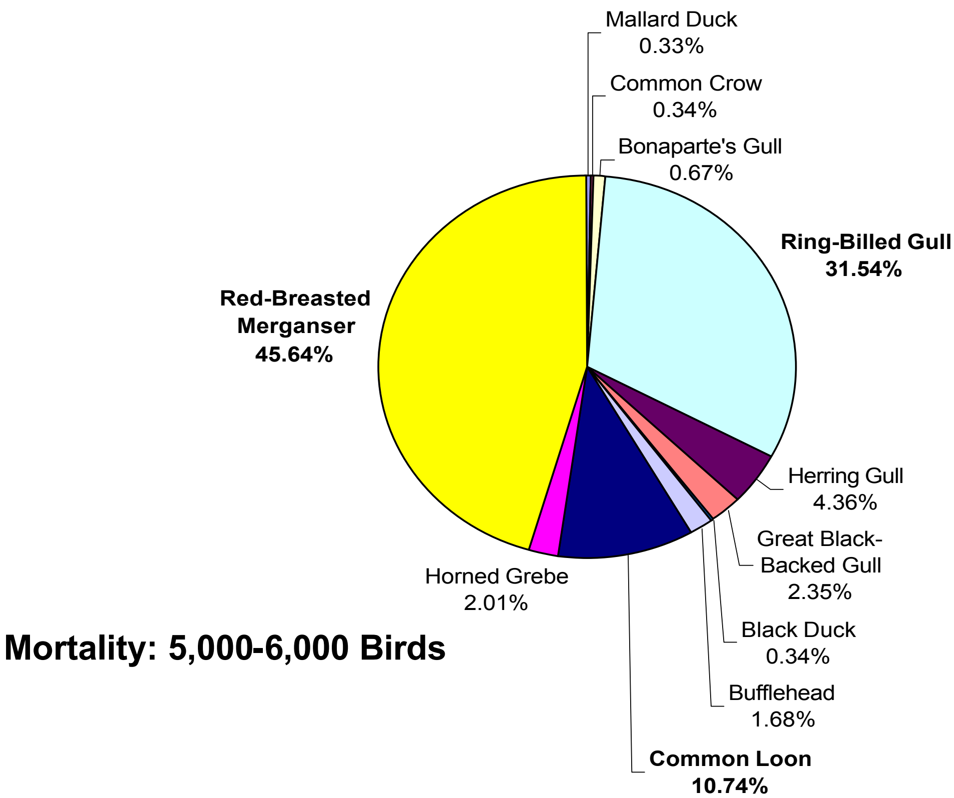


Figure 11.8: Percent mortality on NY Lake Erie shoreline by species observed, fall 2000



Migration of Die-off Events

In 1999, botulism type E mortality was first observed in October along beaches at Pinery Provincial Park, Ontario on Lake Huron and beaches west of Rondeau Bay, Ontario in the central basin of Lake Erie. The Lake Huron event involved primarily common loons while the Lake Erie event was primarily red-breasted mergansers.

In 2000, there were no reports from Lake Huron. The major mortality was observed along stretches of shoreline in the central basin of Lake Erie, primarily the area east of

Rondeau Bay and near Presque Isle Bay, Pennsylvania. Starting in 2000, fish die-offs in late summer saw the first bird die-offs of gulls. Fall events involved gulls, cormorants, common loons and grebes.

In 2001, the mortality events moved further east into the eastern basin of Lake Erie with some reports from the north shore of the western basin but not in any numbers. In the late fall of 2001 large numbers of red-breasted mergansers were killed along with an estimated several thousand common loons during November and December.

Photo: Mike Weimer, U.S. Fish & Wildlife Service

In 2002, there was virtually no observed mortality in the western or central basins, but large mortalities observed at several locations in the eastern basin. Large numbers of gulls at a colony near Buffalo, New York died during July. A major event occurred over the Labour Day weekend at Long Point involving gulls, cormorants and shorebirds as well as thousands of fish (mostly sheepshead as well as a sturgeon). In the November to December period, several thousand common loons and grebes were again encountered dead in the eastern basin and thousands of long-tailed ducks washed ashore dead from apparent botulism type E poisoning. During this period there were also reports of dead common loons washing ashore on Lake Huron from Goderich to Kincardine in Ontario. During the botulism type E events in the eastern basin, several adult sturgeon were found washed ashore, mostly in New York, which is a real management concern for this small population in Lake Erie. The same can be said of the mouth of the Niagara River on Lake Ontario as the last two years have seen reports of dead sturgeon and birds there due to apparent botulism type E poisoning as well.

In 2003, there were not any remarkable events in the summer and early fall on Lake Erie. Common loons and grebes were found dead on beaches of the eastern basin, but at much lower numbers than in previous years. As well, birds apparently suffering from botulism type E were recovered further north in Lake Huron (between Kincardine and Port Elgin, Ontario) and in eastern Lake Ontario. Government employees and private citizens continue to monitor the beaches on Lakes Huron, Erie and Ontario to report fish and bird die off events that may be related to botulism type E or other causes.

What Do We Know to Date

Most initial work concentrated on counting the numbers of fish and birds being affected by the botulism outbreaks. This only served to identify the possible locations of the die-offs in the lake and did little to help understand the mechanism for the toxin getting into the food chain or the environmental conditions on the bottom of the lakes that led to production of toxin at levels that start to affect the food chain.

The current thinking on what is causing these outbreaks is that ecological changes in the Great Lakes due to recent non-native species invasions have changed the way the food chain operates, with much more energy in the system staying on or near the bottom of the lake. When zebra and quagga mussel populations expanded into the Great Lakes there were no observable occurrences of unusual mortalities in wildlife or fish that tend to consume them as food (e.g. scaup ducks, freshwater drum or sheepshead). Over the last eight years, there has been the more recent invasion of the round goby into the Great Lakes and this has seen a tremendous change in fish productivity in Lake Erie where the bulk of the fish biomass is now dominated by these bottom dwelling fish. Formerly, the fish community was much more balanced, and it is thought that very rarely would the benthic community, where the botulism toxin is thought to be produced, be able to mobilize the toxin into the upper levels of the food web. Consequently, much of the current research effort is working to determine if this theory is indeed valid.

Alicia Perez-Fuentetaja and Theodore Lee at the State University of New York in Fredonia are currently studying bottom ecology near Dunkirk, New York to better understand possible triggers for toxin production. Preliminary results suggest that ambient water temperature may be important. They also measured redox potential at the bottom and found that the lowest value generally preceded summer outbreaks by several days in 2002. Results are not complete for 2003 when no major summer events were observed. U.S. EPA/Great Lakes National Program Office and the U.S. Fish and Wildlife Restoration Act funded this project.

At Cornell University Paul Bowser and Rod Getchell have been examining the prevalence of the botulism bacteria in healthy, moribund, and dead fish in areas of confirmed botulism outbreaks and in unaffected areas in Lake Erie and Lake Ontario. Answers will be sought to the questions: is the bacterium more likely to be present in healthy, moribund or dead fish; is one species of fish more likely to carry the bacterium; does the toxin form in fish prior to and after death and, are fish carrying the bacterium associated with waterfowl death events? The researchers are working with the New York State DEC to collect fish, primarily carp and round gobies, from both lakes for examination. Tests will assess the cause of death as well as other pathogens present in the fish. The New York Sea Grant Program funds this project.

In Ontario, Richard Moccia at the University of Guelph has been working with Health Canada to study the behavior of various native and non-native fish species to known doses of botulinin toxin. Fish studied or proposed to be studied are: round goby, walleye, yellow perch and possibly lake sturgeon and mudpuppies. This study is designed to enable a better understanding of the role, if any, that key fish species play in the bird deaths occurring within the Great Lakes. This study attempts to refute, or support, the current working hypothesis that fish and mudpuppies represent a potential "living transport vector" of botulism neurotoxin in the lake, and that they may be a primary source of lethal doses of the type E toxin to affected bird populations. Furthermore, this work will also contribute to a better understanding of the ecology of botulism neurotoxin production in the Great Lakes, and help to assess the potential for human health consequences resulting from the infection, or intoxication, of freshwater fish and birds with *Clostridium botulinum* (Types E botulism). Environment Canada, Ontario MNR, Health Canada and the University of Guelph support this work. As well, wildlife pathologists with New York DEC in Albany and the Canadian Co-operative Wildlife Health Centre at the University of Guelph continue to examine dead birds and fish submitted during these outbreaks to determine cause of death and retrieve specimens for further assessment.

A much more complete description of monitoring and research on botulism in the Great Lakes is available at the following link hosted by New York, Pennsylvania and Ohio Sea Grant at: www.nyseagrant.org/. This link lists proceedings from annual workshops held in 2001, 2002 and 2003 on botulism in the Great Lakes.

11.11 The 2005 Fall Turnover Incident *(Prepared by Jim Grazio, Pennsylvania Dept. of Environmental Protection)*

Because phosphorus is a key macronutrient governing eutrophication in the Great Lakes, Annex 3 of the Great Lakes Water Quality Agreement set forth specific goals with respect to its control. For Lake Erie, these specific goals were "substantial reduction in the present [1978] levels of algal biomass to a level below that of a nuisance condition in Lake Erie" and "restoration of year-round aerobic conditions in the bottom waters of the central basin of Lake Erie." As a result of binational efforts to reduce phosphorus loading from municipal sewage discharges, household detergents, agriculture, and other major sources, phosphorus loading to Lake Erie decreased by over 50% since 1965 and phosphorus concentrations reached record lows in 1995. It seemed to all observers that the cultural eutrophication of Lake Erie had been halted and that the target loads and specific management goals for phosphorus had been attained. In the last decade, however, phosphorus concentrations in Lake Erie have begun to increase once again and signs of cultural eutrophication are again apparent. Nuisance growths of *Cladophora*, *Microcystis* and other undesirable algae are again being reported and seasonal dissolved oxygen depletion in the central basin may be intensifying.

Both the central and eastern basins of Lake Erie thermally stratify into a warmer upper layer (epilimnion) and cooler lower layer (hypolimnion) in the summertime. The epilimnion of the lake maintains its life-giving dissolved oxygen through the photosynthesis of aquatic plants and algae and by mixing with oxygen from the air. The dark hypolimnion is isolated from the oxygen rich epilimnion, and oxygen levels naturally decrease throughout the summer growing season as the result of aquatic organism respiration and the biochemical oxygen demand of decomposing plant matter. With an average depth of 25 meters (82 ft.), oxygen is never completely depleted in the eastern basin. In the central basin, however, with an average depth of 18 meters (60 ft.), the size of the hypolimnion is much smaller and the water may become devoid of oxygen by the end of the summer growing season. As the limiting macronutrient for aquatic plant growth, increases in the amount of bioavailable phosphorus fertilize the growth of algae, thereby accelerating the rate of eutrophication in the lake.

Monitoring of dissolved oxygen levels in the central basin by the US E.P.A.'s Great Lakes National Program Office has suggested that the rate of dissolved oxygen depletion in the central basin hypolimnion may be increasing and that the depletion may be occurring earlier in the summer. For example, average dissolved oxygen concentrations of less than 1.0 mg/L were recorded by the end of August in the central basin during 2001, 2002, and 2003—a hypoxic condition documented only twice in the monitoring period of record from 1985 through 2004. Still, the data are quite variable from year-to-year and definitive trends and causes have yet to be established. Nonetheless, dramatic additional evidence that central basin hypoxia is intensifying occurred on September 29, 2005 when a large "burp" of anaerobic gases was released from the central basin during the annual fall overturn. Hydrogen sulfide odors were detected by residents along the southern shore from roughly Cleveland, Ohio to Buffalo, New York, causing mild panic among some lakeshore residents and prompting hundreds of phone calls to regulatory and law enforcement agencies. Odors were typically described as "rotten eggs", "sewer gas", or "sulfur", generating widespread speculation of causes ranging from sewage treatment facility upsets to natural gas leaks to distant chemical plant explosions. Emergency response teams were called in to investigate the source of the odors in one Pennsylvania community. Fortunately, an experimental, real-time monitoring buoy deployed in the central basin by the National Oceanic and Atmospheric Administration's International Field Year on Lake Erie (IFYLE) effort allowed scientists to correlate the sulfurous odors to the abrupt mixing of the upper and lower layers of the central basin of Lake Erie.

The "big burp" of 2005 was a not-so-subtle reminder of the importance of systematically monitoring water quality parameters and conditions related to the onset of hypoxia in the central basin. More generally, it was a reminder of the importance of ongoing monitoring and research to truly understand and manage the ever-changing Lake Erie ecosystem. It is also important to note that without the nutrient controls imposed on point and nonpoint sources, unpleasant conditions related to the lake turnover would be a lot more common.

11.12 References

Anonymous 2003. Toward a national plan on invasive alien species: a discussion document, September 16, 2003.

Bailey, S.A., I.C. Duggan, C.D.A. van Overdijk, P.T. Jenkins and H.J. MacIsaac. 2003. Viability of invertebrate diapausing eggs collected from residual ballast sediment. *Limnol. Oceanogr.* 48:1701-1720.

Blokpoel, H. and G.D. Tessier. 1996. Atlas of colonial waterbirds nesting on the Canadian Great lakes, 1989-91. Part 3. Cormorants, gulls, and island-nesting terns in the lower Great Lakes system in 1989. Tech. Rep. Ser. No. 225. [Place of publication unknown]: Canadian Wildlife Service, Ontario Region. 74 p.

Bur, M. T., S.L. Tinirello, C.D. Lovell, and J.T. Tyson. 1999. Diet of the double-crested cormorant in western Lake Erie. In *Symposium on double-crested cormorants: population status and management issues in the Midwest* (technical coordinator M. Tobin), pp. 73-84. U.S.Dept. of Agriculture, Animal and Plant Health Inspection Service. Technical Bulletin No. 1879.

Burns, N., D. Rockwell, P. Bertram and J. Ciborowski. In review. Assessment of Lake Erie central basin monitoring data, 1983 to 2002. Submitted to Journal of Great Lakes Research.

Burnett, J.A.D. 2001. Dynamics of yellow perch in northeastern Lake Ontario with emphasis on predation by cormorants, 1976-1999. M.S. thesis, SUNY College of Environmental Science and Forestry, Syracuse, New York.

Byappanahalli, M.N. 2003. Persistence and growth of *E.coli* and enterococci in *Cladophora* in nearshore water and beach sand of Lake Michigan. Great Lakes Beach Association Annual Meeting, October 22, 2003.

Byappanahalli, M. N., D. A. Shively, M. B. Nevers, M. J. Sadowsky, and R. L. Whitman. 2003. Growth and survival of *Escherichia coli* and enterococci populations in the macro-alga *Cladophora* (Chlorophyta). FEMS Microbial Ecology 46: 303-211.

Canale, R.P. and M.T. Auer. 1982. Ecological studies and mathematical modeling of *Cladophora* in Lake Huron: 5. Model development and Calibration. J. Great Lakes Res. 8:112-125.

Carter, H.R., A.L. Sowls, M.S. Rodway, U.W. Wilson, R.W. Lowe, G.J. McChesney, F. Gress and D.W. Anderson. 1995. Population size, trends and conservation problems of the double-crested cormorant on the Pacific Coast of North America. Colonial Waterbirds 18 (Special Publication 1):189-215.

Chotkowski, M.A. and J.E. Marsden. 1999. Round goby and mottled sculpin predation on trout eggs and fry: field predictions from laboratory experiments. *J. Great Lakes Res.* 25:26-35

Corkum, L.D., W.J. Arbuckle, A.J. Belanger, D.B. Gammon, W. Li, A.P. Scott and B. Zielinski. 2003. Potential control of the round goby (*Neogobius melanostomus*) in the Laurentian Great Lakes using pheromone signaling. *Biological Invasions* (ms accepted).

Courtenay, W.R., Jr., D.A. Hensley, J.N. Taylor, and J. A. McCann. 1984. Distribution of exotic fishes in the continental United States. Pages 41-77 *in* Distribution, biology and management of exotic fishes (Eds. W.R. Courtenay, Jr. & J.R. Stauffer, Jr.). Johns Hopkins University Press, Baltimore, Maryland.

de LaFontaine, Y and G. Costan. 2002. Introduction and transfer of alien aquatic species in the Great Lakes-St. Lawrence River drainage basin. Page 73-91 *in* Alien Invaders in Canada's waters, Wetlands and Forests (Eds. R. Claudi, P. Nantel & E. Muckle-Jeffs). Natural Resources Canada, Canada Forest Service, Science Branch, Ottawa.

Dextrase, A. 2002. Preventing the introduction and spread of alien aquatic species in the Great Lakes. Pages 219-231 *in* Alien Invaders in Canada's waters, Wetlands and Forests (Eds. R. Claudi, P. Nantel & E. Muckle-Jeffs). Natural Resources Canada, Canada Forest Service, Science Branch, Ottawa.

Emery, L. 1985. Review of fish species introduced into the Great Lakes, 1819-1974. Great Lakes Fishery Commission. Tech..Rept. No. 45, Ann Arbor, Michigan.

Fuller, P.L., L.G. Nico, and J.D. Williams. 1999. Nonindigenous fishes introduced into inland waters of the United States. American Fisheries Society Special Publication 27, Bethesda, Maryland.

Gladden, J.E. and L.A. Smock. 1990. Macroinvertebrate distribution and production on the floodplains of two lowland headwater streams. Freshwater Biology 24:533-545.

GLRR - Great Lakes Research Review. 2001. Volume 5, number 2.

Grigorovich, I.A., R.I. Colautti, E.L. Mills, K. Holeck, A.G. Ballert and H.J. MacIsaac. 2003a. Ballast-mediated animal introductions in the Laurentian Great Lakes: retrospective and prosective analyses. *Can. J. Fish. Aquat. Sci.* 60:740-756.

Grigorovich, I.A., A.V. Korniushin, D.K. Gray, I.C. Duggan, R.I. Colautti and H.J. MacIsaac. 2003b. Lake Superior: an invasion coldspot? *Hydrobiologia* 499:191-210.

Hatch, J.J. 1995. Changing populations of Double-crested Cormorants. Colonial Waterbirds 18 (Special Publication 1): 8-24.

Higgins, S. N., R. E. Hecky, and S. J. Guildford. 2005a. Modeling the growth, biomass, and tissue phosphorus concentration of *Cladophora glomerata* in the eastern basin of Lake Erie: Model description and field testing. J. Great Lakes Res. 31:439-455.

Higgins, S. N., E.T. Howell, R. E. Hecky, S. J. Guildford, and R. E. Smith. 2005b. The wall of green: The status of *Cladophora* on the northern shores of Lake Erie's eastern basin 1995-2002. J. Great Lakes Res. 31(4):547-563.

Howell, E.T. 1998. Occurrence of the alga *Cladophora* along the north shore of eastern Lake Erie in 1995. Ontario Ministry of the Environment. ISBN 0-7778-8172-1.

International Joint Commission. Ripple Effects Bulletin. Volume 4, May 2003.

Jackson, J.A. and B.J.S. Jackson. 1995. The Double-crested Cormorant in the South-Central United States: Habitat and population changes of a feathered pariah. Colonial Waterbirds 18 (Special Publication 1):118-130.

Johnson, T.B., A. Allen, L.D. Corkum and V.A. Lee. 2003. Density and biomass estimates for round gobies (*Neogobius melanostomus*) in western Lake Erie (ms submitted).

Junk, W.J., P.B. Bayley and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Pp. 110-127. In: Dodge, D.P. (ed). Proceedings of the International Large River Symposium (LARS). Can. Spec. Publ. Fish. Aquat. Sci. 106.

Kirsch, P.H. 1895. A report upon investigations in the Maumee River basin during the summer of 1893. *Bull U.S. Fish Comm.* 14 (1894): 315-337.

Kolar, C.S. and D.M. Lodge. 2002. Ecological predictions and risk assessment for alien fishes in North America. *Science* 298:1233-1236.

Kraft, C. Zebra Mussel Update #19. December 17, 1993. Wisconsin Sea Grant Newsletter.

Krohn, W.B., R.B. Allen, J.R. Moring, and A.E. Hutchinson. 1995. Double-crested Cormorants in New England: Population and management histories. Colonial Waterbirds 18 (Special Publication 1):99-109.

Lake Erie Millennium Network, 2003. Summary of Conference Findings. The Third Biennial Conference of the Lake Erie Millennium Network. May 6-7, 2003.

Leach, J.H. 2001. Biological invasions of Lake Erie. *Point Pelee Natural History News* 1: 65-73.

Lantry, B.F., T.H. Eckert and C.P. Schneider. 1999. The relationship between the abundance of smallmouth bass and double-crested cormorants in the eastern basin of Lake Ontario. In: Final report to assess the impact of double-crested cormorant predation on the smallmouth bass and other fishes of the eastern basin of Lake Ontario. NYSDEC Special Report. N.Y.S. Dept. Environ. Conserv. and U.S. Geological Survey.

Lee, V.A. 2003. Factors regulating biomass and contaminant uptake by round gobies (*Neogobius melanostomus*) in western Lake Erie. M.Sc. Thesis, University of Windsor, Windsor, Ontario.

Lowe, R. L., and R. W. Pillsbury. 1995. Shifts in benthic algal community structure and function following the appearance of Zebra mussels (*Dreissena polymorpha*) in Saginaw Bay, Lake Huron. J. Great Lakes Res. 21: 558-566.

Marsden, J.E. 1993. Responding to aquatic pest species: control or management? *Fisheries* 18:4-5.

Michard, D. The Great Lakes and Power Production: A sustainable relationship. Sustainable water resources workshop. Ann Arbor. MI. April 5, 2005.

Mills, E.L., J.H. Leach, J.T. Carlton and S.L. Secor. 1993. Exotic species in the Great Lakes: a history of biotic crises and anthropogenic introductions. *J. Great Lakes Res.* 19:1-54.

Nichols S.J., G. Kennedy, E. Crawford, J. Allen, J. French III, G. Black, M. Blouin, J. Hickey, S. Chernyák, R. Haas and M. Thomas. 2003. Assessment of lake sturgeon (*Acipenser fulvescens*) spawning efforts in the lower St. Clair River, Michigan. *J. Great Lakes Res.* 29:383-391.

Nicholls, K.H. and H.J. MacIsaac. 2004. Euryhaline, sand-dwelling testate rhizopods in the Great Lakes. *J. Great Lakes Res.* (in press).

Obert, Eric. Botulism workshop highlights: 2001-2003. In: Botulism workshop proceedings. March 25th, 2004. Pennsylvania Sea Grant.

Rudstam, L.G., A.J. VanDeValk, C.M. Adams, J.T.H. Coleman, J.L. Forney, and M.E. Richmond. 2004. Double-crested cormorant predation and the population dynamics of walleye and yellow perch in Oneida Lake, New York. Ecological Applications (in press).

Steinhart, G.B., E.A. Marschall and R.A. Stein. 2004. Round goby predation on smallmouth bass offspring in nests during simulated catch-and-release angling. *Transactions of the American Fisheries Society* 133: 121-131.

Taylor, R.M., M.A. Pegg and J.H. Chick. 2003. Some observations on the effectiveness of two behavioural guidance systems for preventing the spread of bighead carp to the Great Lakes. *Aquatic Invaders* 14: 1-5.

Trapp, J .L., S. J. Lewis, and D. M. Pence. 1999. Double-crested cormorant impact on sport fish: literature review, agency survey, and strategies. In *Symposium on double-crested cormorants: population status and management issues in the Midwest* (ed. M. Tobin), pp. 87-96. United States Department of Agriculture, Animal and Plant Health Inspection Service. Technical Bulletin No. 1879.

Trautman, M.B. 1981. The fishes of Ohio. Ohio State University Press. Columbus, Ohio.

Tyson, L.A., J. L. Belant, F. J. Cuthbert, and D.V. Weseloh. 1999. Nesting populations of double-crested cormorants in the United States and Canada. In Symposium on double-crested cormorants: population status and management issues in the Midwest, ed. M. Tobin, PP. 17-25. U.S. Department of Agriculture, Animal and Plant Health Inspection Service. Technical Bulleting No. 1879.

United States Coast Guard. 1993. Ballast water management for vessels entering the Great Lakes. Code of Federal Regulations 33-CFR Part 151.1510

United State Fish & Wildlife Service. 2001. Draft Environmental Impact Statement: Double-crested Cormorant Management. 174 p.

Vásárhelyi, C. and V. G. Thomas. 2003. Analysis of Canadian and American legislation for controlling exotic species in the Great Lakes. *Aquatic Conservation Marine and Freshwater Ecosystem* 13: 417-427

Weseloh, D. V., P. J. Ewins, J. Struger, P. Mineau, C. A. Bishop, S. Postupalsky, and J. P. Ludwig. 1995. Double-crested cormorants in the Great Lakes: changes in population size, breeding distribution, and reproductive output between 1913 and 1991. *Colonial Waterbirds* 18:48-59.

Section 12: Pathways to Achievement

Photo: U.S. Fish & Wildlife Service, Lee Karney

12.1 Introduction

Many different projects and programs have been implemented in the Lake Erie basin over the years, some of them binational in scope. Most programs have focused on one particular issue or medium, such as water quality, fish populations, contaminated sediments, physical processes, reducing phosphorus, controlling discharge from industries and wastewater treatment plants, monitoring, etc. The LaMP addresses these same issues but from an ecosystem perspective. The ecosystem approach allows a more holistic, comprehensive assessment of problems and the management actions needed to address them. To the extent possible, implications of management actions are reviewed for the entire ecosystem and not just the ecosystem component the action is meant to address. Many times research, assessment and management needs are not coordinated with each other. With the involvement of all the jurisdictional agencies around the lake, researchers, the private sector and the public, it is the LaMP's intention that programs are not designed in a vacuum, that the most important issues will be identified, and that limited resources will be applied to the highest priorities.

The goal of the LaMP is to describe the current state of the lake and set objectives to achieve what we, as the Lake Erie community, envision for a sustainable Lake Erie ecosystem in the future. As described in Section 3, the Lake Erie vision and ecosystem management objectives consider ecological issues (fisheries, wildlife habitat, etc.), socio-economic issues (resource uses/benefits from the lake), and health issues (both ecological and human). The LaMP will provide a road map to lead us toward these objectives. Many of the management and remedial actions that will be recommended in the LaMP will need to be adopted and implemented under other programs and by the agencies that have jurisdiction over those particular areas/issues in question. The LaMP has already leaned heavily on some existing programs for the vision, ecosystem management objectives, and beneficial use impairment assessments.

The watershed is widely regarded as an appropriate unit to manage natural resources. As part of the Lake Erie LaMP process, the Fuzzy Logic Model developed by and for the LaMP identified land use as the single most important driver of in-lake conditions. Watershed management focuses on these uses and the sources of contaminants associated with land based activities. As the Lake Erie LaMP progresses, existing and developing watershed plans around the lake will need to be tapped to provide the most effective means to achieve the goals of the Lake Erie LaMP. The current and future LaMP work plans will need to have a strong focus on ways to connect to local watershed plans. Each of the LaMP partner agencies will need to review their domestic programs in relation to how they can complement the binational programs underway.

A number of federal, state, provincial and local government programs and policies are already in place serving to improve Lake Erie environmental quality. Many of these complementary programs are referenced throughout the Lake Erie LaMP document. Listed in Section 12.2 are some of the binational programs that support LaMP goals and represent some binational paths to achievement.

Photo: Upper Thames River Conservation Authority

12.2 Connections to Existing Binational Programs

Remedial Action Plans

In addition to the development of LaMPs, the GLWQA called for the development of Remedial Action Plans (RAPs) for the Great Lakes Areas of Concern. There are 12 Areas of Concern in the Lake Erie watershed (Section 9). The RAPs and the LaMP process are very similar in that they use an ecosystem approach to assessing and remediating environmental degradation, focus on the 14 beneficial use impairments listed in Annex 2, and utilize a structured public involvement process. The RAPs for the St. Clair River and the Detroit River are also binational in scope. However, although the RAP and LaMP programs are alike in theory, they are very different in practice.

The RAPs have a much smaller geographic focus, looking at single watersheds or parts of watersheds. Although there is a component that considers the impact of that particular Area of Concern on Lake Erie, the main focus is on environmental degradation in that specific area and remediating the beneficial use impairments locally. Public participation in the RAPs is quite robust and very hands-on as the stakeholders are working on projects in their own backyards, and many times have the lead on those projects. Implementation has been underway in most RAPs for a number of years using a combination of federal, state, provincial and local resources. In most cases, the causes of impairment are related to sources within the Area of Concern.

Any improvement in an Area of Concern will eventually help to improve Lake Erie, but the effect will be much more visible and measurable locally. In some cases, remediation of a contaminated site within an Area of Concern may have impacts on the entire lake, particularly if the cleanup involves removal of a source of persistent toxic substances. It is important to continue to cultivate a strong connection between the RAPs and the LaMP, particularly in establishing priority actions that will be most effective in restoring the Lake Erie basin. Updates and the current status of Lake Erie's RAPs are included in Section 9.

Great Lakes Fishery Commission

The Great Lakes Fishery Commission oversees a binational, Great Lakes basinwide fisheries management program. The role of the Great Lakes Fishery Commission is to conduct coordinated fisheries research on the lakes and recommend measures that will permit the maximum sustained productivity of stocks of fish of common concern between the U.S. and Canada. They also have the responsibility to formulate and implement a program to eradicate or minimize sea lamprey populations in the Great Lakes. The Great Lakes Fishery Commission takes into account water quality, habitat and other environmental factors, with the main goal of preserving and enhancing the fish community by supporting establishment of a healthy Lake Erie ecosystem. The Lake Erie Committee (LEC) of the Great Lakes Fishery Commission develops and implements the management strategy specific to Lake Erie. Members of the LEC have been very active in developing the vision and ecosystem management objectives for the Lake Erie LaMP, and some of the LEC's goals and objectives for Lake Erie were used as the basis against which to determine the status of several of the beneficial use impairments. The LEC is also the major action arm of the Great Lakes Fishery Commission that oversees the implementation and development of operational plans under the binational inter-jurisdictional *Joint Strategic Plan for Management of Great Lakes Fisheries.* The Joint Strategic Plan was adopted in 1981 in response to the need to better coordinate fisheries and ecosystem management initiatives. The Joint Strategic Plan was revised in 1997 to strengthen fisheries and ecosystem management coordination based on lessons learned since the 1981 signing and in regard to implementation of the Great Lakes Water Quality Agreement. Building strong ties with the LaMPs and RAPs is particularly specified in the goals of the Plan.

North American Waterfowl Management Plan

The North American Waterfowl Management Plan (NAWMP) is a strategic framework to protect, enhance and create 6 million acres of wetland habitat critical to waterfowl and other wetland wildlife in Canada and the U.S. The goal is to restore waterfowl populations to the averages observed during the 1970-1979 period. The NAWMP was developed in cooperation with all the applicable state, provincial and federal wildlife management agencies. Objectives are translated into action through "joint venture areas". Joint ventures are regional public/private partnerships where the partners agree to develop goals and objectives for a particular species or habitat in a particular geographic region. An example is the Lake Erie Marshes Focus Area Plan, which applies to the Lake Erie basin in Ohio. The plan calls for enhancement and restoration of 7,000 acres of existing protected wetland habitat and acquisition or protection of 11,000 additional acres.

Photo: Dave Menke, U.S. Fish & Wildlife Service

Great Lakes Binational Toxics Strategy (GLBTS)

Although there has been significant reduction in the amount of contaminants released directly into the Great Lakes, there is a continuing presence of persistent toxic substances resulting from atmospheric deposition, contaminated sediment, releases from certain industrial processes, non-point source runoff and the continuous cycling of substances within the lakes themselves. Inter-basin transfer of persistent toxic substances from one lake to another, and the short-range and long-range movement and deposition of these substances from air, prompted U.S. EPA and Environment Canada to sign the Great Lakes Binational Toxics Strategy (GLBTS) in 1997. The goal of this binational strategy is to work towards the virtual elimination of persistent toxic substances resulting from human activity, particularly those that bioaccumulate. Specific reduction targets for the Great Lakes basin have been set for many of the contaminants of concern in the Lake Erie LaMP, with a primary emphasis on achieving reductions using pollution prevention.

The GLBTS states that more strategic and coordinated interventions are required at various geographic scales from the local watershed/area of concern to the lakewide, basinwide, national and international arenas. The Lake Erie LaMP looks to the GLBTS to provide some support for the reduction of out of basin sources, particularly those related to atmospheric long-range transport. The GLBTS reaffirms the two countries' commitment to the sound management of chemicals, as stated in *Agenda 21: A Global Action Plan for the 21st Century* and adopted at the 1992 United Nations Conference on Environment and Development. The GLBTS is also guided by the principles articulated by the International Joint Commission's Virtual Elimination Task Force.

The Lake Erie Millennium Network

The Lake Erie Millennium Network (LEMN) is a collaborative group formed to address lakewide issues. Binational, federal, state, provincial, and local agencies, advocacy groups, and companies whose mandate or concerns relate to the condition of Lake Erie voluntarily sponsor this open, self-assembled association. Formed in 1998, the LEMN evolved from independent efforts by scientists at four research institutes in the U.S. and Canada. Each group had hosted brainstorming sessions to consider the causes and assess possible solutions to complex, lakewide environmental problems. The Network formed with the realization that coordinated, ongoing research was needed to understand the lake, but that most funding opportunities are short-term grants to address specific environmental problems identified by the agencies. Research initiatives were only likely to receive agency support if they were seen to be relevant to the most pressing needs of the agencies. The LEMN provides the major research arm of the Lake Erie LaMP.

To ensure that the Network would be a truly binational and collaborative project, four co-conveners coordinate it. The conveners are research institutions whose members actively interact and collaborate with the broader Lake Erie community of researchers, managers, and public groups. The co-conveners are:

- Great Lakes Institute for Environmental Research, University of Windsor
- U.S. EPA's Large Lakes Research Station, Grosse Ile
- National Water Research Institute, Environment Canada
- Ohio Sea Grant - F.T. Stone Laboratory, Ohio State University

Funding for activities is solicited from organizations that have a responsibility or mandate related to the status of Lake Erie. Agencies who have elected to formally participate and who have contributed financial support through either competitive grants or donations are designated and acknowledged as sponsors. Collaborating agencies are organizations that are active participants in the planning, information transfer, or research aspects of the Millennium project. Collaborators provide in kind and/or technical support that further the goals of the Network.

The LEMN was formed with three objectives:

1) To summarize the current status of Lake Erie;
2) To collectively document the research and management needs of users and agencies; and
3) To develop a framework for a binational research network to ensure coordinated collection and dissemination of data to address the research and management needs.

Lake Erie resource managers and concerned individuals attended the initial workshop in 1998 to identify and prioritize the most pressing problems and data needs facing Lake Erie. Seven major issues were identified:

1) Eutrophication
    a) limits to production
    b) land use issues
2) Contaminants
3) Habitat
4) Non-native invasive species
    a) dreissenids
    b) other exotic species
5) System processes (diversity, stability, trophic transfer)
6) Population dynamics/exploitation of fishes
7) Other issues
    a) human health
    b) policy

Beginning in 1999 and every two years thereafter, the LEMN has organized a binational scientific conference to exchange and summarize information on the status of Lake Erie and its biological and physical processes. The first conference was convened to summarize the state of scientific knowledge on Lake Erie, forecast trends for the next few years, and identify critical research gaps. Forty-eight invited speakers gave presentations, organized into seven sessions:

- Physical features
- Loadings and flux
- Environmental features
- Open-water biotic processes
- Nearshore and coastal biotic processes
- Invaders
- Human-related concerns

Speakers were asked to cast their special expertise in the context of the previously identified management and data needs. Each speaker provided a brief historical survey and described the changes through the 1990s to the present. They then speculated on the next three to five years. Lastly, they identified major research questions/data needs necessary to improve understanding and predictive ability.

Several common themes emerged in discussion sessions after the presentations. Priorities included needs to:

- understand the linkages in energy and contaminant flow between the land immediately surrounding the lake and the lake itself;
- understand the linkages in energy and contaminant flow between the lake bottom and the mid-water regions and their biota (especially the top predators - fishes and birds);
- understand the present and likely future role of non-native invasive species in the Lake Erie ecosystem;
- anticipate the effects of environmental warming on the lake's physical and biological structure; and
- gain a better grasp of whether the rate of change in Lake Erie is accelerating or slowing down.

Fundamental to all concerns was the need to ensure that a suite of basic physical, chemical, environmental, and biological variables, key to monitoring the pulse of Lake Erie, is measured regularly, reliably, and consistently.

Summaries of conference findings and abstracts of the presentations are posted at the LEMN web site (http://venus.uwindsor.ca/erie2001/index.html). The proceedings for the first conference will appear in 2004 as a publication on the present and expected future state of Lake Erie, entitled *Lake Erie at the Millennium - Changes, Trends, and Trajectories*, published by Canadian Scholars' Press.

Since the initial workshops and 1999 conference, presenting scientists and co-conveners have participated in a series of 'research needs' workshops with the aim of developing a research strategy that will address each of the most pressing research issues, at the same time generating data needed to resolve uncertainties in the fundamental management issues (monitoring). Three workshop series have been convened to date. Meeting agendas, summaries of presentations and findings are posted at the LEMN web site. The topics included:

Eutrophication and limits to production in Lake Erie

- *Energy Limitation at the Base of the Food Web*, Grosse Ile, Michigan, September 1999 (hosted by the Large Lakes Research Lab of U.S. EPA)
- *Energy Limitation at the Base of the Food Web - Re-evaluation*, University of Windsor, November 2003

Contamination Processes in Lake Erie

- *Trends, Loadings, and Spatial Patterns-Compartments*, Presque Isle State Park, Erie Pennsylvania, September 2000 (sponsored by Pennsylvania Department of Environmental Protection and Pennsylvania Sea Grant)
- *Mechanisms and Processes* (forthcoming)
- *Ecosystem Implications* (forthcoming)

Habitat

- *Planning needs for a research strategy to understand habitats in the Lake Erie basin,* University of Windsor, May 2002
- *Development of an integrated habitat classification system for the Lake Erie basin,* University of Windsor, December 2002
- *Restoring and maintaining ecosystem integrity of habitats in the Lake Erie basin,* Windsor, February 2003 (sponsored by U.S. EPA)
- *Evaluating impacts of urban development and agriculture on natural habitats* (forthcoming)

Each of the workshop series has resulted in the generation of research plans that have formed the foundation for proposals submitted to granting agencies.

The first research needs workshop, held in 1999, addressed eutrophication and limits on production at the base of the food web. Participants proposed a series of investigations to distinguish whether phosphorus concentrations in the lake were being regulated most strongly by changes in amounts of phosphorus entering the lake, physical limnological processes, or changes in the food web (notably zebra mussels). When surprisingly high concentrations of phosphorus were reported at the 2001 LEMN binational conference, the U.S. EPA called for a coordinated research initiative to investigate the possible causes. This led to U.S. EPA providing funding and many Network researchers undertaking the previously proposed research plan. It is expected the findings will help explain the causes of increasing spring phosphorus concentrations in the water and whether episodes of anoxia in the central basin are due to known processes or possibly to new changes in the food web.

On the recommendation of the contamination processes workshop, an extensive review was commissioned to evaluate how persistent contaminants are transferred from Lake Erie sediments to resident biota (Gewurtz and Diamond 2004). Several proposals written to address recommendations of the workshop have been submitted to funding agencies, with limited success to date.

The habitat research workshop panel has proposed adoption of a single, integrated classification scheme and map of the entire Lake Erie basin that would summarize the kinds and quality of habitats using common terminology and units. Proposals written to request funding for pilot scale evaluation of the classification have not yet been successful.

A long-term goal of the LEMN is to develop and submit two linked research proposals. One will be sent to the Natural Sciences and Engineering Research Council of Canada to form a Great Lakes Research Network. The second will be submitted to the U.S. EPA Science to Achieve Results (STAR) Ecosystem Protection Research program or other suitable funding source. Explicit in the goals of the research program will be the need for longer-term (four to five year horizon) commitment to the collection, compilation, interpretation and application of data to test specific, well-designed *a priori* hypotheses. Proposals will emphasize the time frame required to implement scientifically sound work. Because the sponsoring agencies will have been involved in identifying the questions and needs, their active support as funding and/or in-kind partners is anticipated. This form of partnership underlies the spirit of research network programs both in Canada and the U.S.

The LEMN has attracted broad participation. Agency managers devote resources for meetings and workshops because they can provide input and receive relevant answers. Researchers gain access to critical data by working with monitoring agencies, have good prospects of receiving support for their investigations, and know that their results will reach those who can influence policy. Most importantly, researchers can take an integrated view of the critical issues and questions.

Photo: Upper Thames River Conservation Authority

Great Lakes Regional Collaboration (Prepared by Dan O'Riordan, U.S.EPA-GLNPO)

On May 18, 2004, President George W. Bush issued Executive Order 12240 which recognized the Great Lakes as a "national treasure." The Order directed U.S. federal agencies to improve the coordination of federal efforts to protect and restore the Great Lakes, and required the Administrator of the U.S.EPA to convene a "regional collaboration of national significance for the Great Lakes." The first convocation of what became known as the Regional Collaboration took place in Chicago on December 3, 2004, when conveners representing the federal government, the eight Great Lakes states, numerous cities, tribes, public interests groups and the region's congressional delegation signed a declaration and set forth a framework for the Collaboration process.

More than 1,500 people representing federal, state, local and tribal governments; nongovernmental organizations; and private citizens participated in a nearly year-long intensive effort to develop draft strategies on eight specific priority areas related to restoring and protecting the Great Lakes. The eight priority areas included: Area of Concern Restoration/Contaminated Sediment Remediation; Coastal Health; Habitat/Species; Indicators and Information; Invasive Species; Nonpoint Source; Persistent Bioaccumulative Toxics (PBT) Reduction; and Sustainable Development.

The key partners (Executive Committee) in the effort included: the Council of Great Lakes Governors; the Great Lakes and St. Lawrence Cities Initiative; the Great Lakes Congressional Task Force; the Federal Great Lakes Interagency Task Force; and representatives of Great Lakes Tribal governments. Though the Executive Order, by its very nature, applies only to the United States, representatives from Canada were observers at key Collaboration events and participated on the eight strategy groups.

On July 7, 2005, these strategies were combined into a single comprehensive draft plan and released for public comment for a 60-day period. Subsequently, the Executive Committee of the Great Lakes Regional Collaboration reviewed the comments to make appropriate adjustments to the draft plan. The plan was made final December 12, 2005, when U.S.EPA Administrator Stephen L. Johnson joined other federal, state, local, and tribal officials in Chicago, where many of them had first met just over a year before to begin the effort.

This plan will serve as a blueprint for U.S. prioritization of current and future actions to restore, maintain, and protect the Great Lakes, and will become part of ongoing Lake Erie LaMP workplans submitted by the U.S. to the binational Lake Erie Work Group. Efforts are underway to further prioritize action items and determine funding mechanisms/options.

The final strategy document can be found at www.glrc.us/. Additional information about the Collaboration can be accessed at www.epa.gov/greatlakes/collaboration.

12.3 Lake Erie LaMP 2006 Work Plan

Outlined in Table 12.1 are projects and programs that the Lake Erie LaMP plans to pursue over the short term (2006-2008) and long term (2006-2010). The work plan is limited to those projects over which the Lake Erie LaMP has control, and does not include those programs implemented by partner agencies under other program mandates. However, LaMP partner programs are key to the successful implementation of the LaMP, and the LaMP partners are encouraged to develop, implement and track agency-specific work plans in support of LaMP goals. A significant task of the LaMP Work Group over the next two years will be to re-examine the LaMP structure to facilitate implementation at a watershed level.

12.1: Lake Erie LaMP Work Plan 2004 - 2010

Deliverable	Completion	Status
1 Ecosystem Objectives, Indicators, and Beneficial Use Impairments		
a In response to changing ecosystem conditions, re-assess the status of beneficial use impairments and clearly identify causes of the impairment.	2010	Ongoing
b Conduct a gap analysis to determine the adequacy of existing programs to restore beneficial use impairments.	2008	Ongoing
c Complete an inventory of activities that support Lake Erie LaMP Objectives.	2006	New
d Examine existing management strategies for tributaries in the Lake Erie basin, watershed and sub-watershed management plans, and relevant policies and legislation gaps that need to be addressed to meet Lake Erie LaMP objectives.	2010	New
e Develop targets to work towards in terms of habitat and biodiversity protection in the Lake Erie basin through LaMP indicators process.	2010	New
f Provide input to RAP teams working on AOCs on the testing and outcomes of Lake Erie LaMP indicators.	2010	New
g Complete selection of recommended Ecosystem Management Indicators.	2008	Ongoing
h Define endpoints for recommended Ecosystem Management Indicators.	2008	New
i Develop monitoring protocol for completed Ecosystem Management Indicators.	2008	New

Deliverable	Completion	Status
2 Land Use Objective: All land use activities result in gains in the quantity and quality of natural habitat in order to support the maximum amount of native biodiversity and community integrity that can be achieved and be sustained for the benefit of future generations		
a Network with other groups to identify existing protected areas and possibilities for expanding the protected areas network.	2008	Ongoing
b Identify existing special management zones/protection measures for lake use (e.g. boating, hunting, and dredging restrictions) designated by all government agencies.	2008	Ongoing
c Support opportunities for the establishment of appropriate conservation areas in Lake Erie.	2006	New
d Encourage protection of more natural areas in the Lake Erie basin.	2006	New
e Determine research needs, information gaps and additional programs to further habitat protection/restoration and improve habitat function through the Lake Erie Millennium Network.	2008	Ongoing
f Encourage better management practices in landscapes containing natural areas or in buffer zones surrounding natural areas. Implement measures to address erosion and runoff, reduce nutrient loadings, and address pesticide use in the basin.	2008	Ongoing
g Establish more functional linkages between protected areas throughout the watershed, particularly in priority watersheds.	2008	New
h Characterize submerged moraines such as the Norfolk moraine.	2008	New
i Establish an emergency response framework to protect key habitats in the Lake Erie basin from development pressures and emerging issues.	2008	New
j Identify and focus efforts on Thames and Grand River watersheds and work to ensure that management plans adequately address lake-effect zones of tributaries along with headwater and upper tributary sections. Monitor before, during and after restoration.	2008	Ongoing
k Prepare status reports for priority watersheds that outline the current status of the ecosystem including headwater and upper reaches of the tributary. Encourage work in headwater areas although this will not be focus of LaMP efforts.	2008	New
l Identify and characterize the condition of priority habitats for restoration work. Determine where Lake Erie LaMP habitat priorities match or overlap with priorities and objectives of other habitat protection and restoration initiatives.	2008	New
m Identify any restoration and rehabilitation efforts already recommended or underway in Lake Erie basin, particularly in priority watersheds. Links to Inventory of Activities.	2008	New
n Adopt a habitat classification system. Use standardized habitat zones and biologically defensible classifications that reflect functional use and interrelationships of each watershed and the Lake Erie basin as a whole.	2008	Ongoing
o Incorporate biodiversity layers and physiographic layers into a binational map and use to help identify areas for protection/restoration and monitoring.	2008	Ongoing
p Identify Lake Erie and associated watersheds in terms of focal or refuge habitats, adjunct habitats, nodal habitats, source areas, and degraded habitats and integrate into binational map.	2008	Ongoing
q Use elements of the binational map with information at the appropriate scale in land use zoning and setting restoration priorities across the Lake Erie basin.	2008	New
3 Nutrient Objective: Nutrient inputs from both point and non-point sources be managed to ensure that ambient concentrations are within bounds of sustainable watershed management and consistent with the Lake Erie Vision.		
a Promote the implementation of land owner incentive programs to encourage agricultural best management practices.	2008	Ongoing
b Promote the implementation of programs to protect groundwater and surface water.	2008	Ongoing

Deliverable	Completion	Status
4 Natural Resource Use and Disturbance Objective: Natural resource uses be managed to ensure that the integrity of existing healthy communities be maintained and/or improved, and provide benefits to consumers.		
a Using new techniques in fish stock assessment assess the status of fish stocks in Lake Erie and increase OMNR's in-house competency.	2006	New
b Promote the implementation of programs to ensure wise stewardship of natural resources and protect the environment in permitting and regulating the extraction of sand, gravel and topsoil by the surface mining method (e.g. Pennsylvania).	2006	New
5 Chemical Contaminants Objective: Toxic chemical contaminant concentrations within the basin be virtually eliminated.		
a Determine process for identifying new critical pollutants (including emerging chemicals) for Lake Erie.	2008	New
b In partnership with the GLBTS, agencies will promote energy conservation program (e.g., U.S. side: U.S.EPA Energy Star Program) within the Lake Erie basin.	2008	Ongoing
c In partnership with the GLBTS, agencies will seek funding to initiate or continue household and agricultural clean sweeps and hazardous waste (HAHW) collection depots in the largest Lake Erie basin cities.	2006	Completed collections in Windsor & SW Ontario
d In partnership with the GLBTS, U.S. agencies will seek funding to initiate and continue Lake Erie basin HAHW education programs that will include information about how individuals can practice home environmental stewardship and how to identify HAHW.	2008	Ongoing
e Produce binational sediment mapping report including a summary of the findings of the sediment workshop held in 2002.	2006	Complete
f Through the United States Geological Survey, undertake a basin-wide initiative to map fish tissue contaminant data, similar to the sediment mapping effort.	2006	Complete
g Calculate a Sediment Quality Index (SQI) for the sediment quality data across the basin.	2006	New
h Communicate sediment quality results to AOCs.	2006	New
i Complete an analysis of source contaminants information in the basin to assess if monitoring gaps exist (e.g., sources with no nearby monitoring data) or if there are sites of unexplained environmental quality (e.g., hot spots with no known sources).	2008	New
6 Non-native Invasive Species (NIS) Objective: Non-native invasive species be prevented from colonizing the Lake Erie ecosystem. Existing invasive species be controlled and reduced where feasible and consistent with other objectives.		
a Identify initiatives, policy/legislation, and remedial options available for aquatic and terrestrial non-native invasive species in the Lake Erie basin.	2008	New
b Promote the development and implementation of legislation and policies protecting Lake Erie from further invasions.	2008	New
c Publicize the need for protection against further NIS introductions by holding workshops and information sessions at key forums.	2008	Ongoing
d Facilitate preparation of educational materials for the public and elected officials.	2008	New
e Continue to track the spread of zebra mussels in Pennsylvania. Artificial substrate samplers are deployed in significant PA lakes and monitored throughout the summer growing season for the presence of settled post-larval mussels.	2006	Ongoing
f Through the Pennsylvania Invasive Species Council develop and implement an invasive species management plan, provide guidance on prevention, control, and rapid response initiatives, and facilitate coordination among regional, federal, state, and local efforts.	2006	New

Deliverable	Completion	Status
7 Science and Monitoring		
a Develop and implement a binational monitoring plan for Lake Erie, facilitating cooperative monitoring that will focus on the needs of the LaMP (Cooperative Monitoring Year).	2004	Complete
b Implement a binational monitoring plan for Lake Erie, facilitating cooperative monitoring that will focus on the needs of the LaMP (Cooperative Monitoring Year).	2009	New
c Support Lake Erie Millennium Network.	2006	Ongoing
d Monitor progress in habitat protection and restoration on Lake Erie through existing programs and newly created programs.	2008	New
e Use combination of GIS-based tools and maps, decision-support systems, and selected indicators relevant to habitat and ecosystem function to evaluate progress in protecting habitats.	2010	New
f Review adoption/implementation of habitat guidelines and natural heritage plans by municipalities in priority watersheds and elsewhere in the Lake Erie basin.	2008	New
g Use indicators and targets developed by the indicator process to monitor habitats and changing land use at the appropriate scale (e.g. watershed, sub-watershed) and by various habitat zones and types.	2010	New
h Continue to track the progress of the Great Lakes Binational Toxics Strategy (GLBTS) program in regard to actions that may reduce loadings of the Lake Erie pollutants of concern.	2008	Ongoing
i Develop a 5-year priority research plan for Lake Erie.	2006	New
8 LaMP Program Management		
a Undertake a review of the structure and membership of the LaMP as it moves towards implementation.	2008	New
b Complete an "orientation package" for new members of the WG and MC.	2008	New
9 Communication and Public Involvement		
a Complete communication products for Vision and Ecosystem Management Objectives.	2006	Ongoing
b Host a RAP / LaMP "sharing experiences" technical workshop.	2008	New
c Complete "Lake Erie Update" publication for 2007.	2008	New
d Provide support to the Lake Erie Public Forum so they can continue to provide input and support to the Lake Erie LaMP process.	2008	Ongoing
e Raise awareness of Lake Erie LaMP among watershed municipalities. Prepare a short (5-10 minute) presentation about the LaMP.	2008	Ongoing
f Notify agency offices in the Lake Erie basin of LaMP habitat protection and rehabilitation priorities to encourage more funding for rehabilitation work.	2008	Ongoing
g Provide input, from a Lake Erie perspective, to habitat protection and restoration efforts in the 12 AOCs in the Lake Erie basin.	2008	Ongoing
h Facilitate and encourage the adoption of sustainable land use practices in priority watersheds and throughout the basin.	2008	Ongoing
i Communicate and explain goals and targets of land use/ habitat components of Lake Erie LaMP to local stakeholders.	2008	New
j Network with individuals implementing federal, state/provincial agricultural best management practices programs.	2008	Ongoing
k Develop and distribute brochures, CDs, and/or fact sheets for priority watersheds. Coordinate where possible, with existing watershed, habitat stewardship or lake programs.	2008	Ongoing
l Communicate habitat protection and restoration success stories in the Lake Erie basin. Link reporting with existing stewardship activities/programs where possible.	2008	New
m Develop a 4 to 6 page summary of broad-scale impacts of non-native invasive species on habitats in the Lake Erie basin in cooperation with LaMP partners.	2008	New
n Catalogue existing habitat protection and restoration information, and put together a "habitat toolbox" for distribution.	2008	New

Glossary

alewife - a small silver-colored fish that is not native to Lake Erie.

alvar - rare landscape on glaciated horizontal limestone or dolomite bedrock along the Lake Erie shoreline. They are at their southernmost range on the Marblehead peninsula and Kelleys Island. Historically there were more, but have since been destroyed, primarily by quarrying. Alvars are populated by drought resistant calcium loving plant species (combination of boreal and prairie species) which are maintained in an open state by drought, wave action and ice formation. These factors retard soil accumulation and the growth of woody species.

ambient - surrounding; usually in reference to existing environmental conditions. For example, ambient water quality would refer to the current water quality conditions in the lake.

anoxia - a condition where dissolved oxygen in the water column is totally depleted.

anthropogenic - of man-made origin, not occurring naturally.

areas of concern - specific areas of 42 tributaries to the Great Lakes where degraded environmental conditions have created an impairment to human or ecological beneficial use of the water body.

Binational Executive Committee - group of senior managers from the Parties (U.S.EPA and Environment Canada) and other federal, state and provincial agencies which oversees the implementation of activities by the Parties to meet the goals of the Great Lakes Water Quality Agreement.

beneficial uses - uses of Lake Erie that are valued by society, such as water quality that is suitable for fishing,drinking, swimming, agricultural, and industrial uses; healthy fish and wildlife populations which support a broad range of subsistence, sport, and commercial uses; and aesthetics.

benthos - bottom-dwelling organisms.

bioaccumulation - the process whereby a contaminant increases in an organism over time in relation to the amount consumed in food or absorbed from the surrounding environment.

biological contaminant – A biological contaminant is a compound produced by an organism rather than by an industrial process. In the Lake Erie LaMP, in regard to the ecosystem objective concerning the control of biological contaminants, the definition also includes pathogens and bacteria.

biomagnification - a cumulative increase in the concentration of a persistent substance in successively higher trophic levels of the food chain.

burrowing mayflies - bottom-dwelling burrowing mayfly larvae (*Hexagenia*), are indicators of high water quality. In the 1950s, mayflies were wiped out in Lake Erie due to poor water quality. Low numbers of mayflies are an indicator of low amounts of dissolved oxygen. Also called Canadian soldiers, June bugs, fish flies.

Bythotrephes - a cladoceran, or water flea. *Bythotrephes longimanus*, the spiny water flea, is a non-indigenous invasive species with a barbed tail spine that competes with fish for zooplankton. The tail spine makes it unattractive to other predators and it has flourished.

carcinogen - a substance that causes cancer.

Cercopagis - a cladoceran related to *Bythotrephes*, which is a zooplankton predator. It is another non-indigenous invasive species poised to enter Lake Erie.

Ceriodaphnia - type of *cladoceran*. Helpful in bioassay studies to determine chemical water quality standards for NPDES permits.

chemical contaminants - naturally occurring, anthropogenic or synthetic chemicals.

chlordane - chemical used as a pesticide until banned by the U.S. in 1983 (except for use in controlling underground termites). Chlordane can accumulate in fish and wildlife tissue and is suspected to be a carcinogen.

chlorophyll *a* - the pigment that makes plants and algae green. Measurement of chlorophyll *a* is used to determine the quantity of algae in the water.

cladocerans/copepods - zooplankton that together make up a major component of the zooplanktonic community. They live in the water column and eat phytoplankton, serving as a link between plants and fish.

Cladophora - a long filamentous type of green algae that attaches to hard surfaces, particularly near the shoreline. Abundant growth is an indicator of phosphorous enrichment.

confined disposal facility - a facility built specifically for the disposal of dredged sediment. Often referred to by the acronym CDF.

critical pollutants - substances that persist in Lake Erie waters and bioaccumulate in organisms living in or near the lake at levels that cause or are likely to cause impairment of beneficial uses.

Diporeia - an amphipod that is an important food source for whitefish, lake trout and smelt, has declined dramatically in the eastern basin due to impacts from the quagga mussel.

diatoms - group of microscopic algae that have rigid cell walls composed of silica. They are an important part of the food chain.

dioxins - chemical byproducts of incineration and some industrial processes that use chlorine. Dioxins can accumulate in fish and wildlife and are suspected human carcinogens.

dissolved oxygen - the amount of oxygen measured in the water.

Echinogammarus - an exotic amphipod that has replaced *Gammarus fasciatus*, another exotic, in many regions in Lake Erie.

ecosystem - the complex of a living community and its physical and chemical environment, functioning together as a unit in nature, with some inherent stability.

ecosystem approach - a comprehensive and holistic approach to understanding and anticipating ecological change, assessing the full range of consequences, and developing appropriate management responses. It integrates water quality management and natural resources management.

ecosystem indicators - measures of progress towards meeting ecosystem objectives. Indicators can range in type from administrative measures of activities such as number of permits issued, to environmental measures such as water chemistry or fish populations.

ecosystem objectives - statements describing the desired conditions within an ecosystem to be attained and maintained (such as: *clean drinking water*). These statements can include specific descriptions of the desired state of the biological, chemical, and physical components of the ecosystem.

embayment - an area of water protected by land forming a bay such as Maumee Bay.

environmental contaminants - substances foreign to a natural system or present at unnatural concentrations. They may be chemicals, bacteria or viruses, or the products of radioactivity. Some contaminants are created by human activities while others are the result of natural processes.

environmental stressors - factors which cause, or have the potential to cause, impairments of beneficial uses of Lake Erie. These factors include chemical, physical, or biological influences on the Lake Erie ecosystem, as well as management practices.

eutrophic - the state of a well-nourished, productive lake that typically exhibits low levels of dissolved oxygen.

eutrophication - the process by which a lake becomes rich in dissolved nutrients and deficient in oxygen, occurring either as a natural stage in lake maturation or artificially induced by human activities such as the addition of fertilizers and organic wastes from runoff.

exposure - any contact between a substance and an individual who has touched, breathed or swallowed it.

exposure pathways - the pathway a contaminant may take to reach humans or other living organisms, and includes drinking water, recreational water and fish/food consumption.

exposure routes - The three major routes that chemical and microbial pollutants enter the human body are by ingestion (water, food, soil), inhalation (airborne), and dermal contact (skin exposure).

food web - the process by which organisms in higher trophic levels gain energy by consuming organisms at lower trophic levels. Humans are at the highest level of many food webs.

forage fish - fish species utilized as principal food sources for major sport and commercial fishes.

fostering - practice of removing an unhatched egg from one nest, hatching it artificially, and placing the chick in a new nest (referred in LaMP 2000 in regard to bald eagles).

Gammarus fasciatus - a non-indigenous invasive amphipod.

Great Lakes Water Quality Agreement - an agreement signed by the United States and Canada to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin ecosystem.

guideline - a recommended limit for a substance or an agent intended to protect human health or the environment that is not legally enforceable (Health Canada, 1998).

hacking - practice of raising animals in captivity, acclimating them to natural conditions and then releasing them into the wild (referred to in LaMP 2000 in regard to bald eagles).

Hexagenia - see burrowing mayfly.

human health - "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (World Health Organization, 1984).

hypolimnion - the cooler, lower most layer of water in a thermally stratified lake.

International Joint Commission - commission established by the Boundary Waters Treaty of 1909, consisting of representatives from both the United States and Canada. The Commission's role is to oversee activities common to the borders of the two countries, including water quality in the Great Lakes.

keystone species - a species that has the ability to structure food webs.

lake effect zone - the area within the tributary where the water of Lake Erie and the river are mixed. This is typically the point at which the tributary reaches lake level. The size of the lake effect zone for every river is different and also varies with rising and falling lake levels. The following is the approximate distance, in miles, of the lake effect zone for each Ohio tributary to Lake Erie: Ottawa River 6.8; Maumee River 14.8; Crane Creek 2.9; Turtle Creek 5.6; Toussaint River 10.0; Portage River 15.7; Muddy Creek 5.2; Sandusky River 15.4; Huron River 4.6; Old Woman Creek 1.3; Vermilion River 1.5; Black River 4.1; Rocky River 0.5; Cuyahoga River 4.5; Chagrin River 0.9; Grand River 3.3; Ashtabula River 1.8; and Conneaut Creek 1.2.

lead - a heavy metal that may be hazardous to health if breathed or swallowed. Lead may bioaccumulate in fish and wildlife.

Leptodiaptomus sicilis - type of *copepod*.

Limnocalanus macrurus - large calanoid native to Lake Erie that has declined due to smelt.

loadings - the amount of pollutants being discharged or deposited into the lake.

macroinvertebrates - animals without backbones (*invertebrates*) that are large enough to be seen with the naked eye. Examples of macroinvertebrates include: crayfish, snails, clams, aquatic worms, leeches, and the larval and nymph stages of many insects, including dragonflies, mosquitoes, and mayflies.

macrophyte - plants of lakes, streams and wetlands that are visible with the naked eye.

mercury - a heavy metal that is a *neurotoxin* and harmful if inhaled or ingested at sufficiently high concentrations. Mercury readily *bioaccumulates* in all aquatic organisms.

mesotrophic - the trophic state of a lake that is in between eutrophic and oligotrophic.

microbial contaminant - micro-organisms (e.g. bacteria, viruses, and protozoa such as *cryptosporidium*) that can cause disease

microcystin - a naturally-occurring, potent liver toxin produced by the algae *Microcystis*.

Microcystis - a blue-green algae that causes algae blooms under eutrophic, high phosphorus conditions. It can be toxic to aquatic life and humans if ingested in sufficient quantities due to the presence of microcystin.

Mysis relicta - freshwater shrimp found primarily in the Great Lakes. A primary food source of lake trout.

natural land - undisturbed, naturally occurring landscapes. Habitat.

neurotoxin - a substance that is known or suspected to impact the nervous system.

nitrogen to phosphorus ratio - nitrogen and phosphorus are both nutrients. The ratio that exists between the two can affect the composition or community of algal species in the water column.

non-native species - species that are not native to an area. They could be exotics, that originate in foreign country, or tranplants into a region to which they are not native, but still within their country of origin.

non-native invasive species – species not native to an area that rapidly spread/reproduce and replace native species in the habitat.

oligotrophic - the state of a poorly-nourished, unproductive lake that is commonly oxygen rich and low in turbidity.

omnivorous fish - fish, such as carp, that eat both plants and animals and are tolerant of poor water conditions.

pelagia - biological community existing in the open waters. Includes organisms floating in the water column or at the surface, as well as free-swimming organism.

persistent bioaccumulative toxic chemicals - chemicals that do not breakdown easily, persist in the environment, and bioaccumulate in plant, animal and human tissues.

piscivores - fish eating fish.

planktivores - plankton feeding fish.

pollutants of concern - in addition to the critical pollutants designated by the Lake Erie LaMP, a second, more comprehensive list of pollutants called pollutants of concern has been developed. For more information on this list, see Section 5.2 of this LaMP document.

polychlorinated biphenyls - A group of toxic, highly persistent and bioaccumulative chemicals used in transformers and capacitors (PCBs). A Lake Erie LaMP critical pollutant for priority action.

polynuclear aromatic hydrocarbon - A petroleum or coal combustion by-product often associated with elevated levels of tumors in fish (PAH).

public health agencies - for Lake Erie, includes the State Departments of Health for Michigan, New York, Ohio, and Pennsylvania; the Ontario Ministry of Health (Provincial); Health Canada (Federal); U.S. Agency for Toxic Substances and Diseases Registry (ATSDR, Federal); U.S. Centers for Disease Control (Federal); Public Health Units (municipalities in Ontario); Public Health Departments (State counties).

phytoplankton - plant microorganisms that float in the water, such as certain algae.

remedial action plan - (RAP) a plan developed and implemented to protect and restore beneficial uses in Great Lakes areas of concern, as required under the Great Lakes Water Quality Agreement.

secchi disk - a black and white patterned disk lowered into the water column to measure water clarity.

sentinel species - a species used as an indicator of overall environmental conditions, particularly contaminants. For example, mayflies (*hexagenia*) and bald eagles.

soluble reactive phosphorus - the part of total phosphorus that bioavailable.

standard - a legally enforceable limit for a substance or an agent intended to protect human health or the environment. Exceeding the standard could result in unacceptable harm.

strategic objective – a big picture more qualitative goal

tactical objective – a more hands-on, measurable, more quantitative goal to track the progress toward meeting the strategic objectives.

total phosphorus - the total concentration of phosphorus found in the water.

toxicological profiles - fact sheets prepared by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), "for hazardous substances which are most commonly found at facilities on the CERCLA National Priorities List and which pose the most significant potential threat to human health, as determined by ATSDR and the Environmental Protection Agency" (U.S. Department of Health and Human Services, 1992).

toxic substance - a substance which can cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological or reproductive malfunctions or physical deformities in any organism or its offspring, or which can become poisonous after concentration in the food chain or in combination with other substances (IJC, 1987).

trophic - having to do with various nutritional levels of the food chain.

trophic guilds - groups of organisms that are similar in their nutritional requirements and feeding habits, such as planktivores, piscivores, omnivores, etc.

weight of evidence approach - the weight of evidence approach considers all high-quality scientific data (i.e. the overall evidence) on adverse health effects from wildlife studies, experimental animal studies, and human studies in combination, toward hazard identification and in weighing the actual and potential adverse health effects of environmental contamination in human populations.

zooplankton - animal microorganisms that float in the water.

Acronyms

AOC - area of concern
AMLE – Adjusted Maximum Likelihood Estimator
ANS -aquatic nuisance species
ATSDR - U.S. Agency for Toxic Substances and Disease Registry
BEC - Binational Executive Committee
BMP – Best Management Practice
BTS - Great Lakes Binational Toxics Strategy: Canada - United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes
BUI - beneficial use impairment
BUIA - beneficial use impairment assessment
CA – Conservation Authority (Canada)
CDF - confined disposal facility
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
CRP - Conservation Reserve Program
CREP - Conservation Reserve Enhancement Program
CSO - combined sewer overflow
DFO – Canada Department of Fisheries and Oceans
EC - Environment Canada
ECA - ecosystem alternative
ECCS – Extensive collaborative comprehensive survey
EJ - environmental justice
EOSC - ecosystem objectives subcommittee
FCGO - fish community goals and objectives as developed by the Lake Erie Committee of the Great Lakes Fishery Commission.
FCM - fuzzy cognitive map model
FIELDS - fully-integrated environmental locational decision support system
GLFC - Great Lakes Fishery Commission
GLI - Great Lakes initiative (Great Lakes water quality guidance - U.S.)
GLNPO – Great Lakes National Program Office (U.S.EPA)
GLSLB - Great Lakes St. Lawrence Basin project (Canada)
GLWQA - Great Lakes Water Quality Agreement
HCB - hexachlorobenzene
IADN - Integrated atmospheric deposition network
IFYLE – International Field Year on Lake Erie
IJC - International Joint Commission
IPCC - Intergovernmental Panel on Climate Change
LaMP - Lakewide Management Plan
LEC - Lake Erie Committee of the Great Lakes Fishery Commission
LEL – lowest effect level
LEMN - Lake Erie Millennium Network
LOEC - lowest observable effect level
LTCP – Long term control plan for combined sewer overflows
MAC - maximum acceptable concentration (used for Canadian guidelines)
MCL - maximum concentration limit (used for U.S. standards and guidelines)
MDEQ - Michigan Department of Environmental Quality
MDNR - Michigan Department of Natural Resources
MISA – Canada's municipal/industrial strategy for abatement
NAWMP - North American Waterfowl Management Plan
NAWQA - National water quality assessment program
NCWQR – National Center for Water Quality Research (Heidelberg College)
NIS - non-indigenous invasive species

NOAA - National Oceanic and Atmospheric Administration
NPDES - National Pollutant Discharge Elimination System
NPRI - National pollutant release inventory (Canada)
NRDC - Natural Resources Defense Council
NSERC - Natural Sciences and Engineering Research Council
NSI - national sediment inventory (U.S.)
NWRI - National Water Research Institute (Canada)
NYSDEC - New York State Department of Environmental Conservation
NYSDOH – New York State Department of Health
ODNR - Ohio Department of Natural Resources
ODH – Ohio Department of Health
OEPA - Ohio Environmental Protection Agency
OMNR – Ontario Ministry of Natural Resources
OSI - Ohio sediment inventory
PAH - polynuclear aromatic hydrocarbon
PEC – Probable effect concentration
PBT - persistent, bioaccumulative toxic chemicals
PCB - polychlorinated biphenyl
PCS – Permit Compliance System (U.S.)
POP – persistent organic pollutant
RAP - remedial action plan
SEL – severe effect level
SOLEC - State of the Lakes Ecosystem Conference
SSO - separate or sanitary sewer overflow
STAR - Science to Achieve Results grant program of U.S.EPA Office of Research and Development
STP - sewage treatment plant
TEC – Threshold effect concentration
TMDL - total maximum daily loads
TRI - toxics release inventory
U.S.EPA - United States Environmental Protection Agency
USGS - United States Geological Survey
WHO - World Health Organization
WWTP - wastewater treatment plant