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, inter-dependence, 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.

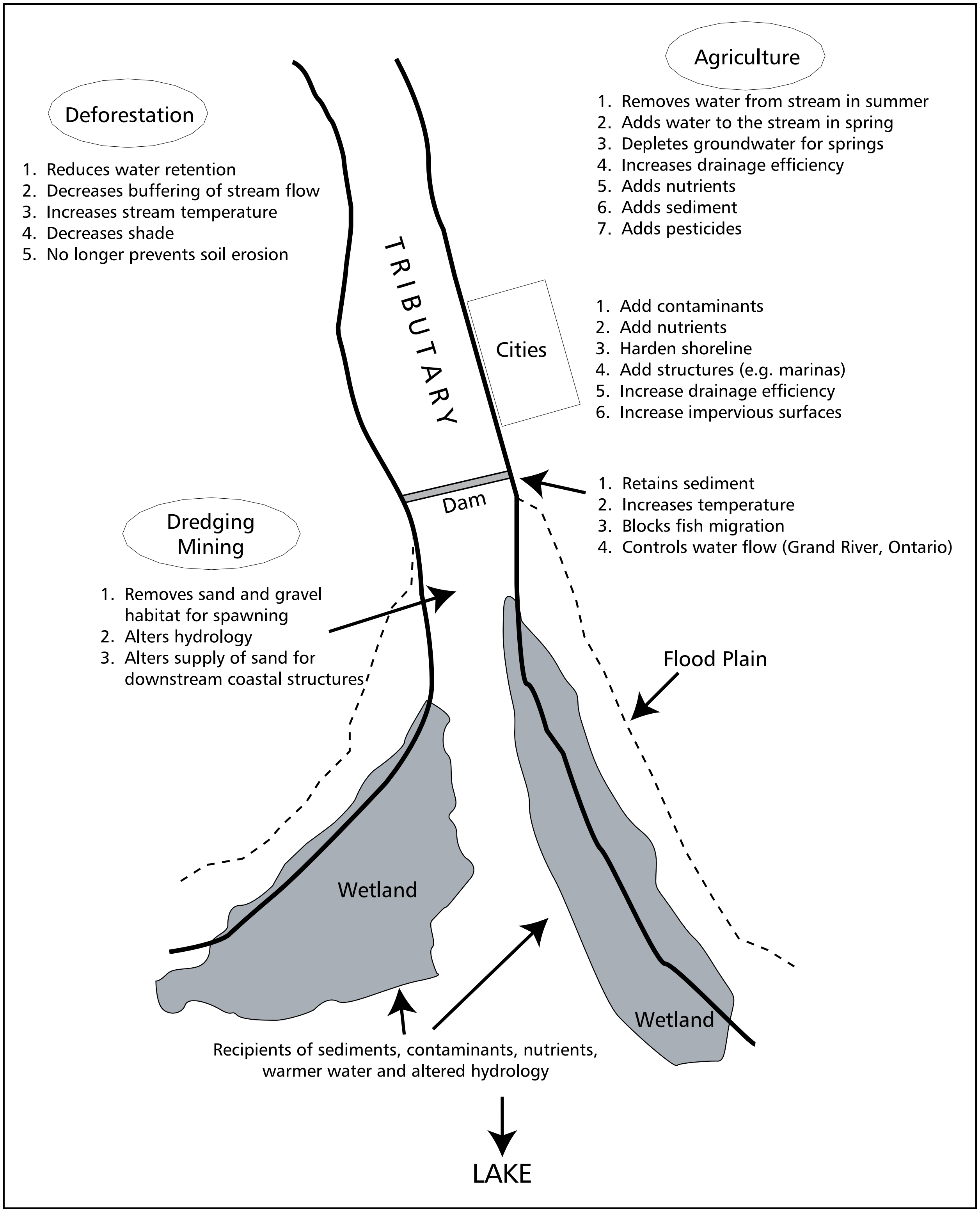
Habitat Zone Stressor/Habitat Type	**Shore Habitat**		**Nearshore Habitat**		
	Interdunal Wetland	Sand Dunes	Submerged Macrophytes	Floating Macrophytes	Emergent Macrophytes
Altered Hydrology					
Altered groundwater - wells, logging		X			X
High water levels - erosion, flooding	X	X	X	X	X
Lack of along 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.

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