This document contains Chapter 7 of the National Coastal Condition Report III.

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National Coastal Condition Report III

Chapter 7: Great Lakes Coastal Condition

December 2008

CHAPTER 7

Great Lakes Coastal Condition

Courtesy of Don Breneman, U.S. EPA GLNPO

Great Lakes Coastal Condition

As shown in Figure 7-1, the overall condition of the coastal waters of the Great Lakes region between 2001 and 2002 is rated fair to poor, with an overall condition score of 2.2. The water quality and fish tissue contaminants indices for the Great Lakes are rated fair, the sediment quality index is rated poor, and the coastal habitat and benthic indices are rated fair to poor. The overall condition and index ratings were derived from indicator findings and the ecological condition of the St. Lawrence River, each of the five Great Lakes, and the St. Clair River-Lake St. Clair-Detroit River Ecosystem presented in the document *State of the Great Lakes 2003* (Environment Canada and U.S. EPA, 2003). This report is the fifth biennial report issued jointly by the governments of Canada and the United States. No additional assessment data for the Great Lakes were collected for the 2001–2002 time period since the results presented in NCCR II (U.S. EPA, 2004a); therefore, the condition estimates presented in this chapter remain unchanged from that report. The next *National Coastal Condition Report* (NCCR IV) will present and discuss data presented in the report *State of the Great Lakes 2005* (Environment Canada and U.S. EPA, 2005) to generate updated condition estimates.

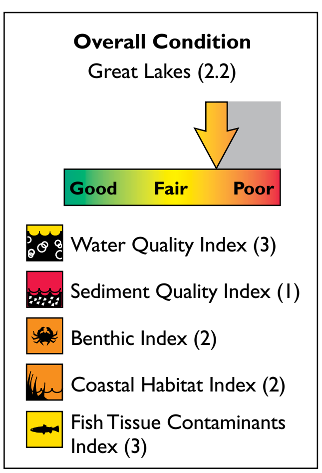


Figure 7-1. The overall condition of Great Lakes coastal waters is rated fair to poor (based on data from Environment Canada and U.S. EPA, 2003).

The 158 coastal counties of the Great Lakes region support a third of the region's population and represent the third-largest coastal population in the nation. The population of Great Lakes coastal counties increased by 6% (1.5 million people) between 1980 and 2003 (Figure 7-2) (Crossett et al., 2004).

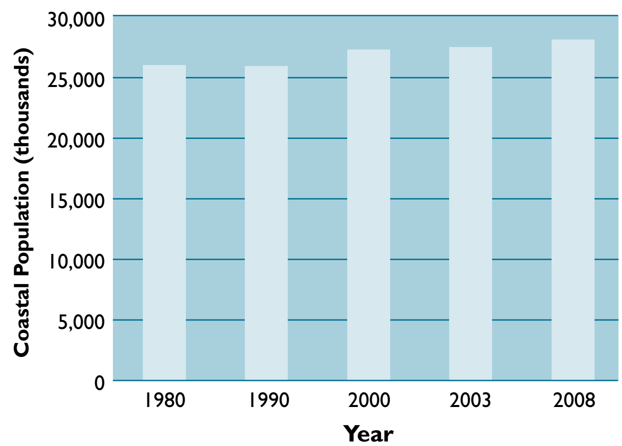


Figure 7-2. Actual and estimated population of coastal counties in the Great Lakes region from 1980 to 2008 (Crossett et al., 2004).

Lake Superior is the largest (in volume), deepest, and coldest of North America's five Great Lakes (courtesy of U.S. EPA GLNPO).

Coastal Monitoring Data—Status of Coastal Condition

Although an extensive monitoring network exists for the Great Lakes region, Great Lakes monitoring is not directly comparable to monitoring conducted under NCA for coastal estuaries and marine waters. The GLNPO uses best scientific judgment to select monitoring sites that represent the overall condition of the Great Lakes, whereas the NCA survey uses a probabilistic survey design to represent overall ecosystem condition and to attain a known level of uncertainty (see Appendix A). The two programs use different methods, and spatial estimates of coastal condition cannot be assigned to the Great Lakes because they would be inconsistent and incomparable with those calculated for the marine coastal regions of the United States. The GLNPO and Great Lakes scientists assess the overall status of eight ecosystem components of the Great Lakes, some of which are similar to NCA indices and indicators. The results of these efforts, along with relevant technical information, are available from two Web sites: the State of the Lakes Ecosystem Conferences (SOLEC) site, available at http://www.epa.gov/grtlakes/solec, and the GLNPO site, available at http://www.epa.gov/glnpo. These results were used to quantify and categorize NCA indices and component indicators for the Great Lakes in the NCCR II and will be summarized briefly in the following sections. The condition values are based primarily on expert opinion and were integrated with other regional condition data to evaluate the overall condition of the nation's coastal environment.

Water Quality Index

The NCCR II assessment combined several SOLEC indicators (e.g., eutrophic condition, water clarity, dissolved oxygen levels, phosphorus concentrations) into a water quality index to allow for comparison of water quality condition estimates for the Great Lakes with the NCA water quality index for U.S. marine coastal waters. The NCCR II rated the Great Lakes water quality as fair. Of the four SOLEC indicators used to develop the water quality index, eutrophic condition was rated fair to poor, phosphorus concentrations were rated fair, water clarity was rated good to fair, and dissolved oxygen concentrations were rated good. It should be noted that low dissolved oxygen levels continue to be a problem in the central basin of Lake Erie during the late summer.

The Great Lakes region hosts the third-largest coastal population in the nation (courtesy of U.S. EPA GLNPO).

Highlight

International Field Years on Lake Erie (IFYLE) Program

One of NOAA's long-term goals is to provide enhanced ecosystem forecasts that predict patterns of biological, physical, and chemical variables in response to natural- and human-induced changes to the system across a variety of spatial and temporal scales. These changes may include extreme natural events, climate change, land and resource use, pollution, invasive species, and fisheries impacts. Ecosystem forecasts ultimately should benefit coastal communities, including those along the Great Lakes, by providing the foundation for the following:

- Improved decision-making for resource stewardship
- Mitigation of potentially hazardous human activities
- Reduced impacts of natural hazards
- Enhanced communication between scientists and managers
- More effective prioritization of science.

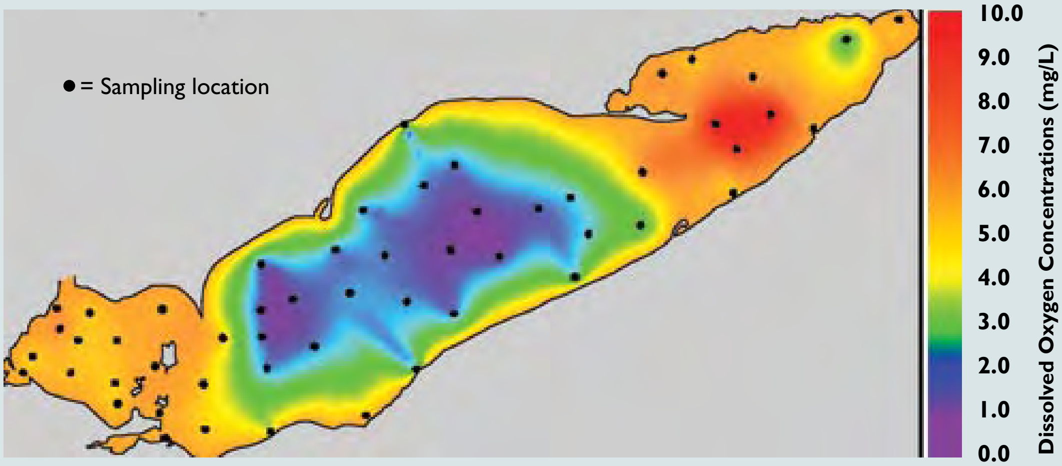
Some of the water quality and ecosystem health issues that persist within the Great Lakes are of concern to the user community and researchers and remain a challenge to Great Lakes resource management. These issues include, but are not limited to, HABs, reduced oxygen availability (hypoxia/anoxia), and the introduction of exotic species. All of these issues have the potential to negatively influence food web dynamics, native biodiversity, and biological production (e.g., fisheries yield). The development of tools to provide reliable forecasts of the Great Lakes ecosystem and its chemical, biological, and physical subsystems would help resource agencies choose among potential management options (NOAA, 2006a).

To improve the ability to provide reliable ecosystem forecasts in the Great Lakes, the NOAA Great Lakes Environmental Research Laboratory (GLERL) has been working toward development of an integrated (multi-agency), multidisciplinary research program for Lake Erie to deal with these important management issues. Lake Erie is an ideal candidate for a pilot ecosystem-forecasting framework development effort. It is small in size relative to coastal marine systems and the other Great Lakes; therefore, cost-effective field sampling can be performed to test hypotheses over the entire lake. A wealth of historical monitoring and research data has been compiled for this system and is available to use for model parameterization/calibration, validation, and ecological scenario testing. In addition, several predictive physical models (e.g., watershed-hydrology models, hydrodynamics models) already exist for Lake Erie. Finally, a large research and policy infrastructure (e.g., Lake Erie Millennium Network, Lake Erie Lakewide Management Plan) already exists and will facilitate efforts to develop truly integrative, multidisciplinary programs aimed at conducting the needed research for ecosystem forecasting (NOAA, 2006a).

This effort to develop a large-scale, integrative research program on Lake Erie began in 2005 with ship support from NOAA and the initiation of the International Field Years on Lake Erie (IFYLE) Program (NOAA, 2007f). This program is based largely on the research hypotheses, ideas, and needs that were generated at a large, international Lake Erie Science Planning Workshop that was hosted by NOAA–GLERL on March 4–5, 2004 (NOAA, 2004a). The three primary objectives of the IFYLE program are the following:

- To quantify the spatial extent of hypoxia across the lake and gather information that can help forecast its timing, duration, and extent

- To assess the ecological consequences of hypoxia to the Lake Erie food web, including the impacts on bacteria, phytoplankton, microzooplankton, mesozooplankton, and fish
- To identify factors that control the timing, extent, and duration of HABs (including toxin formation) in Lake Erie, as well as enhance our ability to use remote sensing as a tool to rapidly map HAB distributions in the lake (NOAA, 2007f).



Preliminary estimation of dissolved oxygen concentrations (mg/L) in Lake Erie bottom waters during September 2005 (courtesy of GLERL, NOAA).

The IFYLE program has become one of the largest international, multidisciplinary research efforts of its kind in Lake Erie's history, costing approximately $5 million and involving about 40 scientists from NOAA, academia, and private institutions throughout North America, Canada, and Europe (NOAA, 2007f). This program can truly be considered integrative, given involvement by numerous U.S. and Canadian universities and federal, state, and provincial agencies. The IFYLE serves as an example of how NOAA and other federal agencies are fulfilling the Presidential Executive Order 13340 (Bush, 2004) to execute the Great Lakes Regional Collaboration among agencies, including NOAA's ship support, EPA GLNPO, NOAA GLERL, the National Sea Grant College Program, the Ohio and New York Sea Grant College programs, Environment Canada, USACE, Ohio DNR, New York State Department of Environmental Conservation (DEC), Michigan DNR, Pennsylvania Fish and Boat Commission, and the Ontario Ministry of Natural Resources (NOAA, 2006a).

The 2005 field program centered on determining the factors regulating the distribution of oxygen concentrations in Lake Erie (see map) and the consequences of low oxygen on the abundance, distribution, and condition of fish and their prey. The remainder of 2005 and all of 2006 were devoted to sample processing, data analysis, testing and refining hypotheses, and building models that can be used for both understanding and forecasting purposes. During 2007, another intensive field season with more focused sampling objectives was conducted (NOAA, 2006a).

For additional information on the IFYLE program, see http://www.glerl.noaa.gov/ifyle or contact Dr. Stuart A. Ludsin (Stuart.Ludsin@noaa.gov) and Dr. Stephen B. Brandt (Stephen.B.Brandt@noaa.gov), co-coordinators of the IFYLE program, Ann Arbor, MI.

Sediment Quality Index

The NCCR II assessment indicated that, for the SOLEC indicators measured, the primary problem in the Great Lakes coastal waters was degraded sediment quality. The sediment quality index for the coastal waters of the Great Lakes region is rated poor, with sediment contamination contributing to the poor condition assessed in many harbors and tributaries and affecting the beneficial uses at all 31 of the U.S. and binational Great Lakes Areas of Concern (AOCs) throughout the region (Figure 7-3). Contaminated sediments are also the leading cause of fish consumption advisories for this region and serve as a source of contaminants to open water as a result of sediment-resuspension activities (Environment Canada and U.S. EPA, 2003).

Benthic Index

The benthic condition of the Great Lakes, as measured by benthic community health, was rated fair to poor in the NCCR II. This rating was based on results of the GLNPO's benthic invertebrate monitoring and surveillance monitoring programs. Populations of the benthic invertebrates *Diporeia* (in cold, deepwater habitats) and *Hexagenia* (in mesotrophic habitats) were used for evaluating benthic heath because of their importance at the base of the Great Lakes food web (Figure 7-4).

Coastal Habitat Index

More than one-half of the Great Lakes coastal wetlands were lost between 1780 and 1980, with the largest losses in Ohio (90%) and the smallest in Minnesota (42%) (Figure 7-5). The coastal habitat index used to assess the condition of Great Lakes wetland condition in the NCCR II was based on amphibian abundance and diversity, wetland-dependant bird diversity and abundance, the areal extent of coastal wetlands by type, and the effects of water level fluctuations. Based on these measures, the coastal habitat index for the Great Lakes region is rated fair to poor.

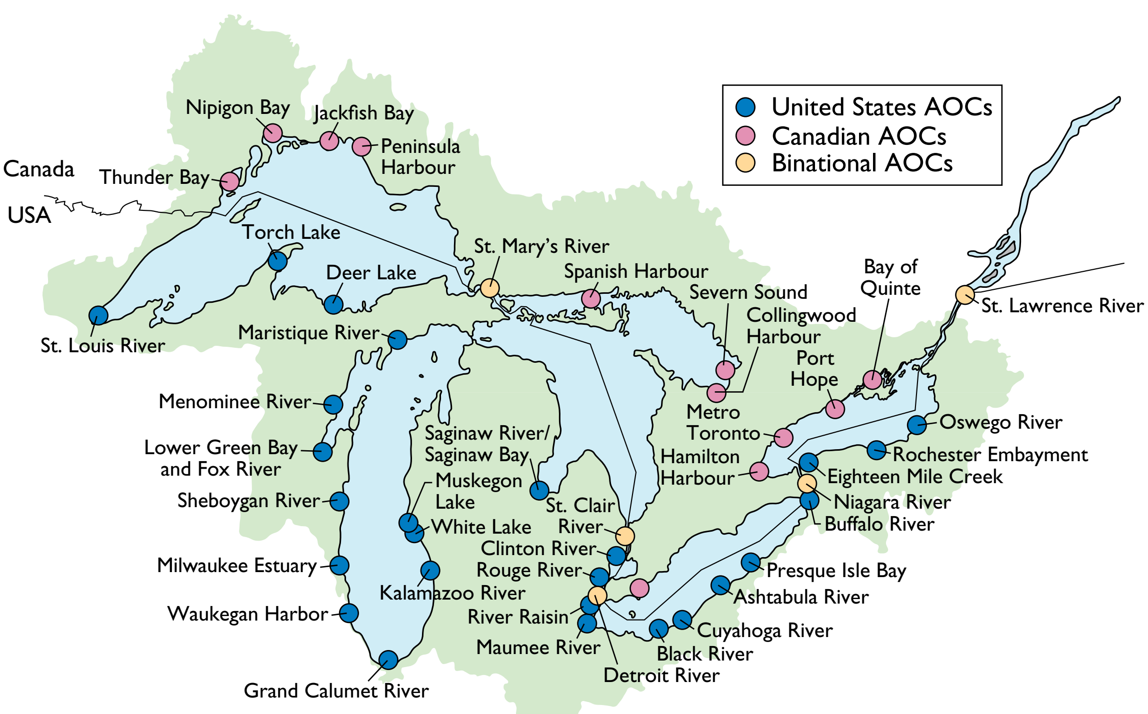


Figure 7-3. Great Lakes Areas of Concern (AOCs) (U.S. EPA, 2007c).

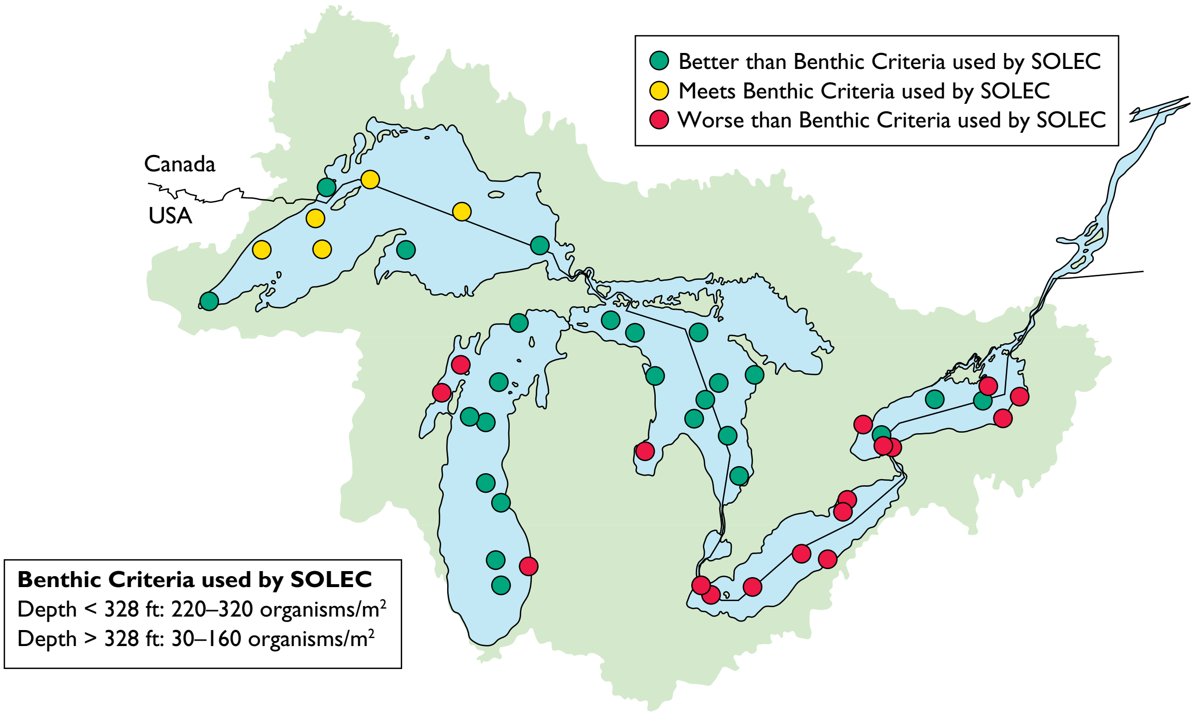


Figure 7-4. 1998 *Diporeia* abundance in relation to benthic criteria (U.S. EPA, 2007d).

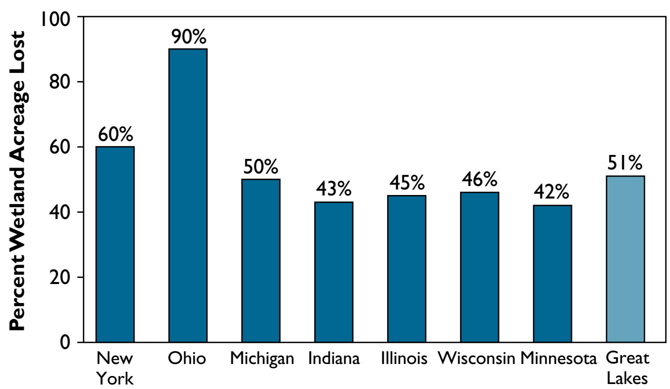


Figure 7-5. Percent coastal wetland habitat loss from 1780 to 1980 by state and for the Great Lakes region overall (Turner and Boesch, 1988; Dahl, 1990).

Lake sturgeon are found in all five of the Great Lakes (courtesy of Wayne Davis, U.S. EPA, Biological Indicators of Watershed Health Photo Library, http://www.epa.gov/bioindicators).

Fish Tissue Contaminants Index

The fish tissue contaminants index for the coastal waters of the Great Lakes region is rated fair, as reported in the NCCR II. Fish advisory programs are well established in the Great Lakes states and offer advice to residents regarding the amount, frequency, and species of fish that are safe to eat. Such advice is based primarily on concentrations of PCBs, mercury, chlordane, dioxin, and toxaphene in fish tissues. Concentrations of these contaminants are generally declining in fish tissues, but are still present at levels that trigger fish advisories for all five Great Lakes. Great Lakes scientists rate fish tissue contamination as fair, based on the application of a uniform fish protocol to PCB concentrations in coho salmon from the Great Lakes (contaminants in fish tissue range between 0.2 and 2.0 ppm). Each lake is rated individually based on PCB concentrations and the corresponding fish advisory category; the final overall rating is an average of all five individual ratings (Environment Canada and U.S. EPA, 2003).

Highlight

Residual Ballast Water and Sediments Pose Aquatic Nuisance Species Threats to the Great Lakes Ecosystem

A 3-year, multi-institutional study (Johengen et al., 2005) completed in 2005 characterized a previously overlooked threat of nonindigenous aquatic species introductions by foreign commercial shipping into the Great Lakes ecosystem. The study was funded by the Great Lakes Protection Fund, NOAA, EPA, and the U.S. Coast Guard. The study examined both types of ballast-related threats to the Great Lakes: the regulated discharge of ballast water from vessels entering the Great Lakes from foreign ports, and the unregulated discharge from vessels that enter the Great Lakes with no ballast on board (NOBOB). The project team included scientists from NOAA, the University of Michigan, the University of Windsor (Canada), Old Dominion University, and the Smithsonian Institution, as well as a ship-operations expert (Philip T. Jenkins and Associates, Ltd.) from Canada.

During the study (Johengen et al., 2005), researchers found small bivalves, including zebra mussels such as those shown above, in the residual ballast sediment from several ships; however, the frequency and abundance of these bivalves was generally low overall (courtesy of the University of Michigan, Center for Great Lakes and Aquatic Sciences and the U.S. EPA GLNPO).

NOBOB vessels are ships loaded to capacity with cargo and therefore carry no declarable ballast on board; however, these empty ballast tanks may hold residual water and sediment containing live organisms, their resting stages, and microorganisms, including human pathogens. Once in the lakes, NOBOB vessels have to ballast with Great Lakes water as they offload cargo, allowing the water to mix with the foreign residuals in the ballast tanks. As outbound cargo is subsequently loaded onto these ships, the mixed ballast water containing the foreign residuals will be discharged. Ballast operations often occur at multiple ports within the Lakes during any single overseas ship transit, providing several opportunities for foreign organisms to be discharged. On average, about 90% of ocean-going ships entering the Great Lakes are NOBOBs (Transport Canada, 2007) and are thus not covered by the ballast water exchange regulations implemented in 1993 by the U.S. Coast Guard (58 FR 18330). These regulations require that pumpable ballast water from foreign sources must be exchanged with open-ocean water and have a salinity exceeding 30 ppt.

The results of three ballast water exchange experiments conducted within this study demonstrated that exchange can be highly effective in reducing the concentration of organisms entrained with coastal ballast water. Comparison across target taxa indicates that, in most cases, ballast water exchange efficacy was > 90%. Results of experiments to determine the additional benefits of "salinity shock" (i.e., replacing low salinity or freshwater ballast taken on in-port with open-ocean seawater) were highly variable, depending on taxa and the form in which they are found in ballast tanks, and should be regarded with caution. The study concluded that ballast water exchange is an imperfect, but generally beneficial management practice in the absence of more effective and consistent treatment options (Johengen et al., 2005).

Ballast sampling includes collection of water and sediment samples to examine the diverse collection of phytoplankton and other invertebrate fauna (courtesy of NOAA Great Lakes NOBOB Assessment Program).

In another study, the team surveyed 103 NOBOB vessels about their ballast management practices and boarded 42 of those vessels to enter and sample residual water and sediment in 82 ballast tanks (see photo). About one-third of the 103 surveyed vessels entered the Great Lakes with freshwater residual ballast. Ships in this condition present the most serious threat of inoculation of new freshwater organisms into the Great Lakes ecosystem. The survey found the total amount of residuals (water plus sediment) per ship ranged from negligible to 200 t, with sediment accumulation generally averaging between 10–15 t (Johengen et al., 2005).

Microbial pathogens and a diverse assemblage of phytoplanton and invertebrate biota, including several species not indigenous to the Great Lakes, were found in the residual ballast water and sediments sampled. The presence of one or more microbial pathogens was detected in 26 of the 42 ships sampled, but the research method only determined presence, not absolute concentrations, so the study cannot definitively assign a human health risk. More than 80% of the samples produced significant phytoplankton growth when inoculated in freshwater media. From these grow-out experiments, 41 nonindigenous taxa were reported, although concentrations tended to be < 5% of the total in most trials. The density of invertebrate resting stages in ship sediments was also examined. Seventy-six distinct taxa were hatched and identified from resting eggs separated from sediment residuals, including 21 nonindigenous species (Johengen et al., 2005).

The study concluded that results of the microbial, phytoplankton, and invertebrate analyses confirm that NOBOB vessels are vectors for the introduction of nonindigenous species to the Great Lakes Basin. Several lines of evidence indicated a decrease in organism abundance in ballast residuals with increasing salinity of residual water and/or flushing with open-ocean water. In addition, tanks that were regularly flushed with small amounts of open-ocean water had, in general, accumulated or retained less sediment. These findings suggest that regular flushing of the tanks with seawater may reduce (but not eliminate) the invasion risk associated with residual ballast material in NOBOB ballast tanks (Johengen et al., 2005). In 2005, the U.S. Coast Guard issued a new policy asking NOBOB vessels entering the Great Lakes to take steps as appropriate to increase the salinity of their residual ballast water to > 30 ppt by saltwater flushing, if not by ballast water exchange (70 FR 51831). In 2006, Canada began enforcing new regulations that all water in ballast tanks of ships arriving from overseas (including the residual water in NOBOBs) must have a salinity > 20 ppt, achieved by ballast water exchange or saltwater flushing, in order for those ships to discharge their ballast water in the Great Lakes (SOR/2006-129 pursuant to section 657.1 of the Canada Shipping Act).

Although the study provided a more comprehensive scientific basis for developing new policies and for identifying possible preventive measures and treatments, the authors recognized that managing the risk posed by NOBOB vessels is a complex problem, and they suggested that such policies and solutions are best developed by participation and cooperation among all involved constituencies, including regulatory agencies, the scientific community, the shipping industry, and the public. New regulations must be carefully considered and constructed to be practicable, enforceable, and verifiable, or they are likely to be ineffective (Johengen et al., 2005).

Trends of Coastal Monitoring Data—Great Lakes Region

The NCCR II rated the overall condition of the Great Lakes as fair to poor for the period 1998 through 2000. No additional assessment data for the Great Lakes were collected in 2001 and 2002, the time period of the current report; therefore, the analysis of trends in environmental condition estimates for the Great Lakes cannot be made at this time.

Assessment and Advisory Data

Fish Consumption Advisories

Fishing in the Great Lakes region is a way of life and a valued recreational and commercial activity for many people. To protect citizens from the risks of eating contaminated fish, the 8 states bordering the Great Lakes had a total of 30 fish consumption advisories in effect during 2003 for the waters and connecting waters of the Great Lakes. During 2003, every Great Lake had at least one advisory, and advisories covered 100% of the Great Lakes shoreline that year (Figure 7-6). Michigan, which borders four of the five Great Lakes and encompasses four of the six connecting waterbodies, issued the largest number of fish consumption advisories (13) (U.S. EPA, 2004b).

Great Lakes fish consumption advisories were issued for six pollutants: mercury, mirex, chlordane, dioxins, PCBs, and DDT. All of the advisories listed PCBs, and one-half (50%) also listed dioxins (Figure 7-7). Lake Superior, Lake Michigan, and Lake Huron were under advisory for at least four pollutants each in 2003 (Table 7-1); however, some of the advisories were of limited geographic extent, and advisories in most locations were applied primarily to larger, older individual fish high in the food web (U.S. EPA, 2004b).

Fishing from shore (courtesy of U.S. EPA GLNPO).

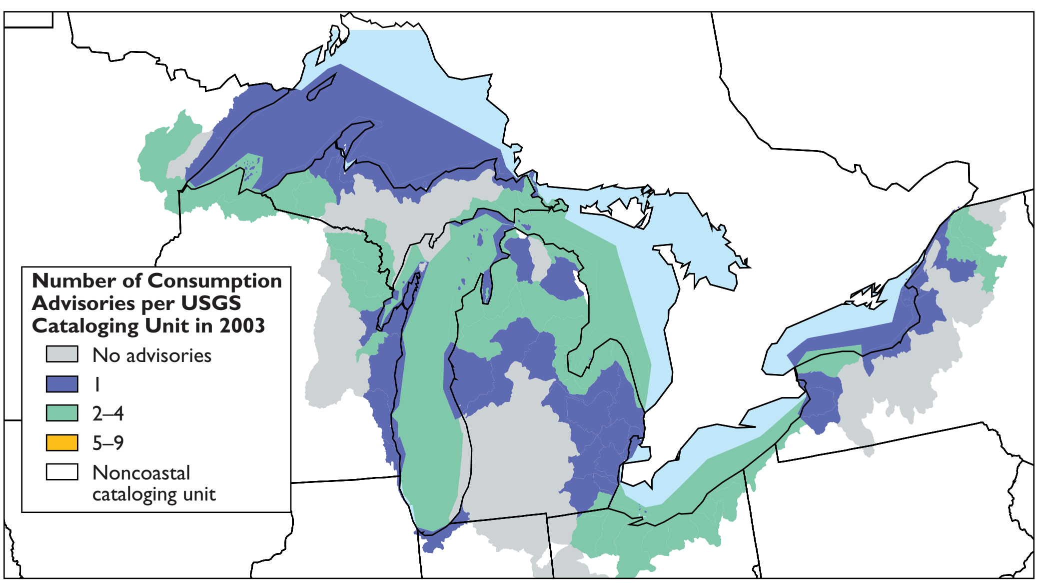


Figure 7-6. The number of fish consumption advisories in effect in 2003 for the U.S. Great Lakes waters (U.S. EPA, 2004b).

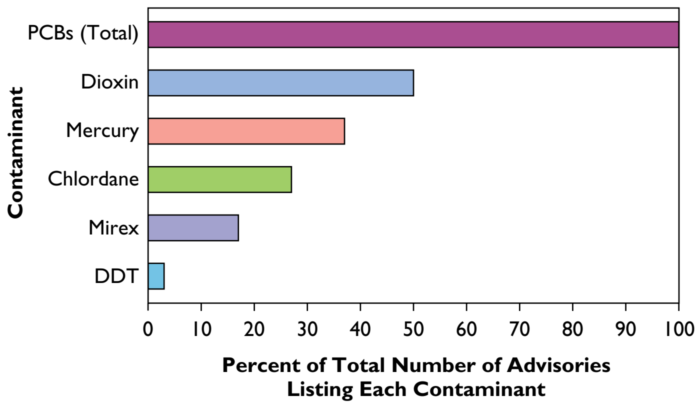


Figure 7-7. Pollutants responsible for fish consumption advisories in Great Lakes waters. An advisory can be issued for more than one contaminant, so percentages may add up to more than 100 (U.S. EPA, 2004b).

The Great Lakes have a long history of fishing activity, as shown by this 130-year old commercial fishing village in Leland, MI (courtesy of the Michigan Travel Bureau and U.S. EPA GLNPO).

Table 7-1. Fish Advisories Issued for Contaminants in Each of the Great Lakes (U.S. EPA, 2004b)

Great Lakes	PCBs	Dioxins	Mercury	Chlordane	DDT	Mirex
Lake Superior	•	•	•	•		
Lake Michigan	•	•	•	•	•	
Lake Huron	•	•	•	•		
Lake Erie	•	•	•			
Lake Ontario	•	•				•

Species and/or groups under fish consumption advisory in 2003 for at least one of the Great Lakes or their connecting waters:

American eel	Burbot	Lake sturgeon	Rainbow trout	Walleye
Black crappie	Channel catfish	Lake trout	Rock bass	White bass
Bloater	Chinook salmon	Lake whitefish	Round goby	White perch
Blue catfish	Chub	Largemouth bass	Silver redhorse	White sucker
Bluegill sunfish	Coho salmon	Longnose sucker	Siscowet trout	Yellow perch
Bowfin	Common carp	Northern hogsucker	Smallmouth bass	
Brook trout	Freshwater drum	Northern pike	Smelt	
Brown bullhead	Gizzard shad	Pink salmon	Splake trout	
Brown trout	Lake herring	Quillback carpsucker	Steelhead trout	

Source: U.S. EPA, 2004b.

Beach Advisories and Closures

Of the 533 Great Lakes coastal beaches reported to EPA, about 33.6% (179 beaches) were closed or under an advisory for some period of time in 2003. Table 7-2 presents the number of beaches monitored and the number of beaches that were closed or under advisory for each state.

The highest percentage of beaches closed or under advisory occurred in Ohio, with 100% of monitored beaches reporting at least one public beach notification in 2003. Pennsylvania did not report the number beaches monitored or advisories/closures issued in 2003. Figure 7-8 presents advisory and closure percentages for each county within each state (U.S. EPA, 2006c).

Table 7-2. Number of Beaches Monitored and Beaches With Advisories/Closures in 2003 for Great Lakes Coastal States (U.S. EPA, 2006c)

State	No. of Beaches Monitored	No. of Beaches With Advisories/Closures	Percentage of Beaches Affected by Advisories/Closures
Minnesota	27	5	18.5
Wisconsin	111	76	68.5
Illinois	46	33	71.7
Indiana	25	18	72.0
Michigan	276	10	3.6
Ohio	20	20	100
Pennsylvania	Not reported	Not reported	Not reported
New York	28	17	60.7
TOTALS	**533**	**179**	**33.6**

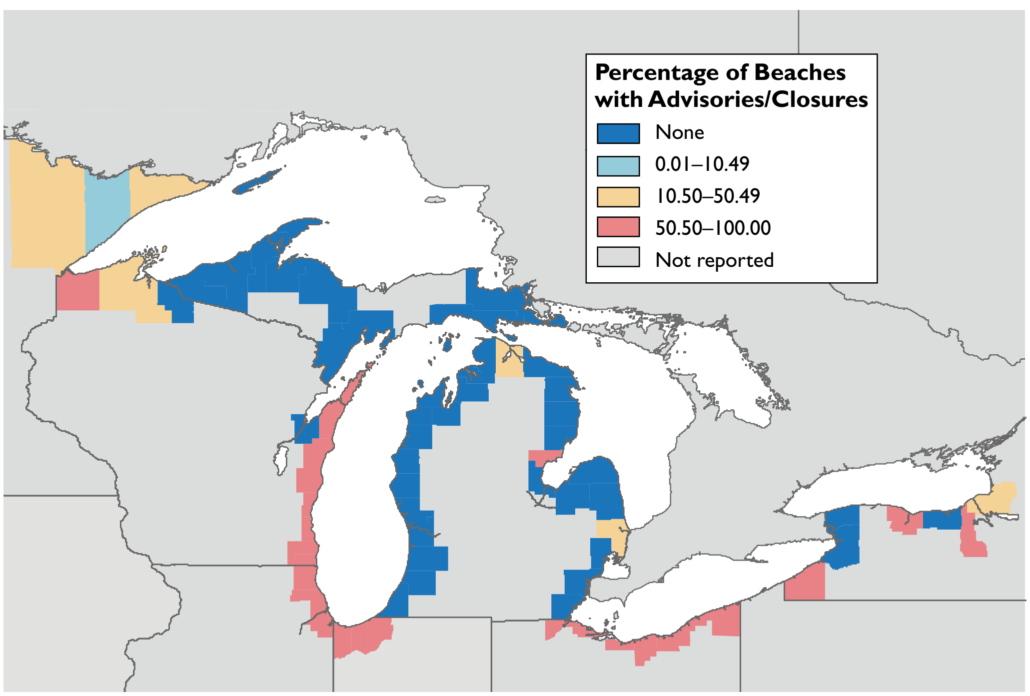


Figure 7-8. Percentage of monitored beaches with advisories or closures, by county, for the Great Lakes region (U.S. EPA, 2006c).

Most beach advisories and closures were implemented at coastal beaches along the Great Lakes because of elevated bacteria levels (Figure 7-9). Some beaches had multiple sources of waterborne bacteria that resulted in advisories or closures. Figure 7-10 shows that unknown sources accounted for 89% of the responses (U.S. EPA, 2006c).

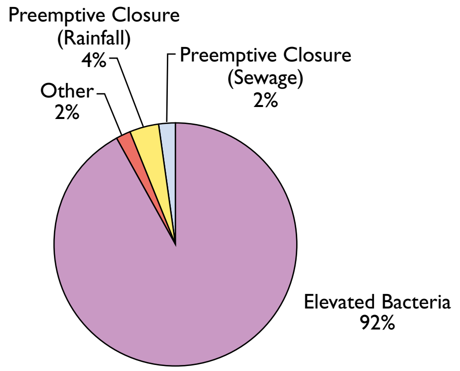


Figure 7-9. Reasons for beach advisories or closures for the Great Lakes region (U.S. EPA, 2006c).

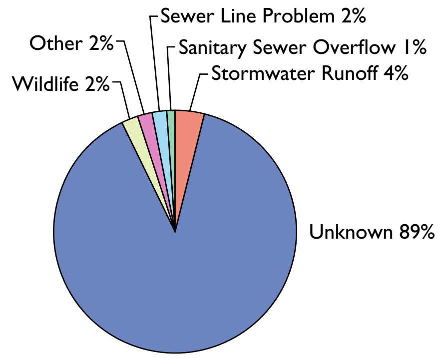


Figure 7-10. Sources of beach contamination resulting in beach advisories or closures for the Great Lakes region (U.S. EPA, 2006c).

Lake Michigan beach near Elberta, MI (courtesy of the Michigan Travel Bureau and U.S. EPA GLNPO).

Summary

Although the Great Lakes has an extensive monitoring network with respect to objectives, design, and approaches, Great Lakes monitoring is not directly comparable with monitoring done by the NCA for estuarine and coastal waters. For example, GLNPO monitoring sites are at locations selected according to best scientific judgment to represent the overall condition of the Great Lakes, whereas the NCA survey monitoring sites are at locations selected using a probabilistic sampling design to yield direct, representative estimates of overall condition with known levels of uncertainty. Consequently, coastal condition spatial estimates that are consistent and comparable with those prepared for the marine coastal regions surveyed by NCA cannot be calculated for the Great Lakes. Instead, the best professional judgment of knowledgeable scientists was used to assess the overall status of eight ecosystem components in relation to established endpoints or ecosystem objectives, when available. The Great Lakes were rated fair to poor using available assessment information. Future reports in the NCCR series will use the NCCR I and subsequent reports as a baseline for the overall health of the Great Lakes to determine if conditions improve in the future as a result of management and control strategies. The results of these future assessments will be used as a basis to compare and integrate the overall condition of the Great Lakes with other coastal resources in this report.

Contamination in the Great Lakes has affected human uses of these waters. In 2003, there were 30 fish consumption advisories covering 100% of the shoreline of the Great Lakes. All of these advisories were issued for PCB contamination (alone or in conjunction with other contaminants). In addition, 33.6% of the region's monitored beaches were closed or under advisory for some period of time during 2003. Elevated bacteria levels in the region's coastal waters were primarily responsible for the beach closures and advisories.