STATE OF THE LAKES ECOSYSTEM CONFERENCE '96

INTEGRATION PAPER

DRAFT FOR DISCUSSION PURPOSES
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S.O.L.E.C. '96 - THE YEAR OF THE NEARSHORE

State of the Lakes Ecosystem Conference 1996

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DRAFT

Prepared for the

SOLEC STEERING COMMITTEE

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Notice To Readers

This Working Paper is part of a series of Working Papers that are intended to provide a concise overview of the status of the nearshore conditions in the Great Lakes. The information they present has been selected as representative of the much greater volume of data. They therefore do not present all research or monitoring information available. The Papers were prepared with input from many individuals representing diverse sectors of society.

The Papers will provide the basis for discussions at SOLEC '96. Readers are encouraged to provide specific information and references for use in preparing the final post-conference versions of the Papers. Together with the information provided by SOLEC discussants, the Papers will be incorporated into the SOLEC '96 Proceedings, which will provide key information required by managers to make better environmental decisions.

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EXECUTIVE SUMMARY

The 1996 State of the Lakes Ecosystem Conference (SOLEC '96) focuses on the state of nearshore ecosystems of the Great Lakes. For purposes of the conference, the nearshore is defined as the area directly affected by the Lakes through hydrology and climatic influence. The nearshore waters are defined as those supporting warm water fisheries.

The purpose of the conference is to provide a forum and bring together experts and decision makers who will benefit from better knowledge of the Great Lakes ecosystem and related information sources.

The five background papers developed for the conference are summarized together with indicators for use in characterizing the state of the ecosystem in each subject area. The background papers address the aquatic nearshore, coastal wetlands, land near the lakes, impacts of changing land use, and information management.

Basic conclusions are:

Nearshore Waters

There is little doubt that the nearshore aquatic environment of the Great Lakes has been altered physically, chemically, and biologically by human activity. About 25 years ago however, with the signing of the Great Lakes Water Quality Agreement, society began to act, and the trend to worsening conditions began to slow down and in the case of water quality, to improve. Large reductions in nutrient loads showed clear results in the lakes and stand as a model for future protection initiatives. Toxic chemical loadings have been reduced as have concentrations in biota. Some problem areas of contaminated sediment remain. Also, persistent bioaccumulative contaminants continue at levels which may be causing problems. Some habitat loss is permanent and habitat losses continue as do losses in biodiversity. Continued vigilance is needed to prevent repetition of past problems.

Coastal Wetlands

The state of coastal wetlands in the Great Lakes ecosystem is known only in part. There is no inventory or evaluation system in place for the majority of coastal wetlands. The general location of coastal wetlands is known from remote sensing and aerial photography, but there is no commonly accepted system of classification, nor is there systematic information as to their quality, rate of loss or rate of degradation. Much is known about the stressors that degrade wetlands and some local areas have been relatively well studied as to their condition, but it is not possible at this time to provide a comprehensive review of the state of Great Lakes coastal wetlands. A limited evaluation of selected wetland features is provided. This evaluation indicates poor or degrading conditions for most features.

Land by the Lakes

The health of the land by the lakes (nearshore terrestrial ecosystems) is degrading throughout the Great Lakes basin. Indicators are provided summarizing the state of: the 17 terrestrial coastal ecosystems; 12 special ecological communities that exist within those ecosystems; and each of the 5 lake basins.

Impacts of Changing Land Use

Land development continues to be the greatest source of stress on the nearshore ecosystem. Over the last half century, the prevailing pattern of development has become urban sprawl, that consumes vast areas of land and destroys natural habitat and farm land. Urban sprawl is inefficient from both an ecological and an economic perspective and is, thus, clearly unsustainable. Improved coordination of planning among jurisdictions, greater use of development restrictions, and serious application of economic incentives to contain urban sprawl are the keys for more sustainable development.

Information and Information Management

Review of the state of information and information systems is summarized using indicators of data: coverage, time frames, applicability and usability. The overall ratings are "fair". The overall finding is that there are no widely accepted indicators for measuring the state of the nearshore, data have generally been collected on an as needed basis by individual agencies, and their utility in assessing the state of the nearshore is questionable in any particular situation.

Major management challenges

- Bringing together existing nearshore ecosystem information into accessible GIS based formats;
- Developing easily understood indicators to support understanding of the state of the system and obtaining wide spread agreement on what needs to be done;
- Integrating the concepts of biodiversity and habitat into existing programs traditionally devoted to pollution control or natural resource management for harvest and
- Integrating Lakewide Management Plans (LAMPs), Fisheries Management Plans and Remedial Action Plans (RAPs) for Areas of Concern so that they become fully viable management mechanisms, useful for decision makers throughout the Great Lakes basin ecosystem in taking action and assessing results.

It is expected that all background papers will be revised following the conference and will be used to prepare a State of the Lakes report similar to the one published in 1995.

1.0 Introduction

This paper is intended to present a summary of background information and major ideas for consideration during the 1996 State of the Lakes Ecosystem Conference (SOLEC '96). Further background information, findings and conclusions are contained in five subject area papers: Nearshore Waters, Coastal Wetlands, Land By The Lakes, Impacts of Changing Land Use (stressors resulting from changing land use), and Information and Information Management which are provided for use before and during the conference.

The 1996 SOLEC conference is the second in a series convened by the Governments of the USA and Canada, the first of which was held in 1994. The 1996 conference is focused on the nearshore areas of the ecosystem, but retains the basic objectives from the earlier conference. The conference objectives are to:

- Provide information on the state of the nearshore ecosystem to help strengthen decision making and management within the basin;
- Develop support for an integrated environmental information system to help direct plans and programs;
- Provide information on existing Great Lakes strategies and build cooperative actions needed to strengthen and complement them;
- Provide a forum for improved communication and network building for involved groups and individuals within the basin.
- Inform local decision makers of environmental issues that affect nearshore areas of the Great Lakes basin.

The focus on the nearshore was chosen because of its ecological importance and because of the concentration of human use and impacts upon it. It was also chosen because of the need to begin to bring together the scattered information sources and many institutions which deal with the nearshore areas and to support an integrated ecosystem perspective.

The background papers give an overview of the state of the nearshore ecosystems, as well as the stressors that impact upon those systems, and the sources of those stressors. In addition, the information management paper examines the state of information on the nearshore ecosystem and its availability. As with SOLEC '94, SOLEC '96 examines the state of the ecosystem including human beings.

Ecosystem health has been assessed in terms of the status of nearshore aquatic communities; the health, productivity and areal extent of wetlands; and the status of the terrestrial plants and animals. The stressors have been described in terms of their trends, and their impacts on the nearshore.

Of the stressors impacting the ecosystem, the largest single category is human use of land. The background paper on changing land use examines land use policies and practices throughout the basin, and gives case study examples of good and bad practices.

1.1 SOLEC '94

SOLEC '94 set the stage for the present conference by looking at conditions throughout the Great Lakes Ecosystem. In preparation for SOLEC 94, seven working papers were prepared on the following topics: 1) state of the aquatic communities; 2) state of human health; 3) state of habitat; 4) trends in contaminants, 5) nutrients and 6) the economy. A paper integrating these topics was also prepared.

The findings in these papers were presented and discussed extensively at the SOLEC 94. Over 400 government and non-government representatives concluded with the findings of the papers that:

- loss of aquatic habitat has been catastrophic, and largely ignored to date by government programs focused on contaminants;
- loss of native species has been equally catastrophic, with a collateral loss of biological diversity among the remaining species;
- non-native species invasions have impacted on ecosystem integrity;
- contaminant concentrations in fish and wildlife, as well as in sediments have declined dramatically since the early 1970s, but are still a problem;
- there is a global component to contamination, which will make virtual elimination of contaminants from the ecosystem very difficult;
- the composition of the food chain is important in contaminant movement within the ecosystem;
- hormone mimicry is an emerging issue to be researched and monitored;
- the present phosphorus control strategies have resulted in attainment of agreed-to targets, but that there is pressure to relax these targets because of the impact of zebra mussels on the ecosystem;
- the maintenance of a healthy economy is essential to restoration of the Great Lakes, and further that in any future SOLEC, economics must be assessed along with other ecosystem stressors;
- human health is no worse as a result of people living in the Great Lakes basin,

than in any other industrialized nation, and is certainly better than in most countries in the world.

The results of the SOLEC were published as the State of the Great Lakes, in August, 1995. In preparation for SOLEC '96, the authors of the background papers for SOLEC '94 were asked to provide an update on the state of ecosystem stressors and the states of ecosystem health that were evaluated in 1994. The authors have concluded the following regarding changes since 1994:

1.2 Aquatic Community Health Update

While the overall evaluation of individual Lakes has not changed, there have been some changes reported in the status of both exotic species and community structure.

1.2.1 Exotic Species

Zebra mussels Range extensions of zebra and quagga mussels are continuing. In Lake Erie, they have now been confirmed to extend distribution onto soft sediments and vegetation. Colonization of deep water sediments by quagga mussels appears to be having a negative impact on *Diporeia.*

Ruffe Ruffe (fish) has now extended its range from Lake Superior to Lake Huron.

Goby The round goby (fish) is expanding its range in the Great Lakes. Only Lake Ontario has not had a range extension reported. In Lake Erie, the species has been found in Eastern Lake Erie and has become more abundant in Central Basin tributaries on the south shore.

Sea lamprey Sea lamprey in northern Lake Huron are increasing in abundance. Inability to control sea lamprey in the St. Mary's River seems to be a major factor in this population explosion.

1.2.2 Community Structure

Lake Superior No major changes in status.

Lake Huron No major changes in status, except for the presence of ruffe.

Lake Michigan No major changes in status.

Lake Erie Lake Erie remains a very stressed ecosystem. Since 1990, walleye, smelt, and yellow perch populations have been declining. An interaction of declining productivity and historically high abundance of walleye in the late 1980s appear to be contributing factors. Zebra mussel densities continue to increase lake-wide. The unexpected extension of zebra mussel distribution to soft sediments means that abundance is likely to continue increasing. Effects of zebra mussel on water clarity of the Detroit River from Lake St. Clair and in Lake Erie have resulted in large improvements in water clarity in some nearshore areas. Associated with these elevated levels of zebra mussels, however, Lake Erie is also experiencing summer blooms of blue-green algae, which is causing problems for water supplies. Finally, recent increases in round goby abundance and the arrival of ruffe in Lake Huron create opportunities for more disruption of aquatic community structure.

Lake Ontario The Lake Ontario ecosystem is experiencing a dramatic decline in productivity. Decreasing nutrient loading from Lake Erie (due to reductions in phosphorus loading and the effects of zebra mussels), has contributed to the collapse of alewife. Levels of abundance of alewife (the principal prey for salmon and trout) continues to be low. Fish management agencies in New York and Ontario have reduced stocking levels salmon and trout in response to the collapse of alewife. On a positive note, lake trout are now showing increasing natural reproduction in Lake Ontario, and a recent sighting of a deepwater sculpin (*Myoxocephalus quadricornis*) indicates that this formerly "extirpated" native species may be recovering.

1.3 Habitat and Wetlands

It is the opinion of the authors of the SOLEC '94 paper on Habitat and Wetlands, that there has been little, if any, recovery in the status of these two features in the Great Lakes, with the exception of improvements in some Areas of Concern (AOCs). On the positive side, habitat as an issue needing attention has gained wider support, and is increasingly becoming important to more agencies and organizations.

The kinds of inventories and assessments proposed in the 1994 paper have NOT been undertaken. As a result, there is no current and adequate trend information such that some measure of gains or losses could be reported. The authors cannot say if the improvements in habitat and wetland restoration in inland areas or in AOCs are enough to offset the losses believed to be occurring at the time of SOLEC '94.

1.4 Human Health

1.4.1 Trends in Environmental Levels of Contaminants

Contaminants There is no evidence of dramatic shifts of the kind or levels of bioaccumulating contaminants in the tissues of residents of the Great Lakes Basin. However, the levels of such contaminants in the tissues of people eating large amounts of Great Lakes fish may be up to several fold higher than in people who do not eat such fish.

Beach closings Available statistics indicate persistent bacterial contamination at many beaches in the Great Lakes basin, especially in late summer. There are not enough studies of illnesses related to recreational use of Great Lakes waters to draw any conclusions regarding trends.

Drinking water The occurrence of outbreaks of cryptosporidiosis in several municipalities in the Great Lakes basin due to contaminated drinking water is an indication that new infectious diseases are emerging. Drinking water analyses still show relatively high levels of trihalomethanes and other toxic water disinfection byproducts in some areas of the Great Lakes basin, and of heavy metals, especially lead , the latter due mainly to lead solders in old plumbing.

Radioactivity Atmospheric and total radioactivity has declined in the Great Lakes basin following the cessation of the above-ground testing of nuclear weapons, and following the Chernobyl disaster.

1.4.2 Hospital admissions and death rates

The available studies on hospital admissions were related to specific regions, recent years, and air pollutants only, and thus can not be used to derive trends. The following indications of trends are based largely on statistics for the whole of Canada. It is likely that the Ontario portion of the Great Lakes basin would show similar trends.

Children The proportion of Canadian children with low birth weights declined during the 1980's from about 8 % in 1980 to about 6 % in 1990.

Hospitalization rates for Canadian children gradually declined during the 1980's . Respiratory and digestive system problems were the most frequent causes for admission, apart from injuries. There has been no dramatic change since then.

Adults No hospitalization statistics for adults in the Great Lakes basin were available for review.

Overall Canadian incidence rates for cancers increased steadily from 1970 to the late 1980's and then appear to have levelled off.

In view of the recent concern about environmental contaminants which are endocrine disruptors, it may be of interest that the rates for cancers of the female reproductive system have continued to decline steadily, while for men the rates for prostate and testicular cancer have increased during the last 20 years.

Cancer is still mostly a disease of older people; therefore as the Canadian population ages, cancer rates may increase in part due to this factor.

1.4.3 Fish Consumption Advisories

Advisories to restrict consumption of fish due to bioaccumulating contaminants are in effect in many parts of the Great Lakes basin.

1.4.4 Contaminant Burdens in Humans

Based on studies of blood samples and breast milk samples, levels of bioaccumulating contaminants in tissues of residents of the Great Lakes basin are similar to those of other regions in the temperate zone, and are lower than those in the far North and Arctic. No significant changes have been reported since 1994. Additional information regarding findings from the Great Lakes Human Health Effects Research Program are presented in Appendix B.

1.4.5 Overall Rating

As in 1994, based on the available limited information, one would have to rate the state of human health in the Great Lakes basin as mixed/improving.

1.5 Toxic Chemicals

Most recent analysis of temporal trend contaminant data in fish communities has indicated that the previous upward trend of most contaminants has ceased and decreases are again being measured in many cases. An exception to this is the recent documentation of toxaphene increases in the Lake Superior system. Retrospective analysis is now underway to identify any potential new sources of this compound.

1.6 Nutrients

The authors of the Nutrients paper have reviewed the data since 1994, and have concluded that there has been no appreciable change in the nutrient status of the Lakes, and that the rating remains "good". The implications of this continued status of lower nutrient concentrations is cause for concern, however, for the fishery (see Section 1.2.2).

1.7 Economy

Although unemployment in the Canadian side of the basin has remained relatively high, there have been improvements in the USA. Industrial restructuring, including continued mechanization and modernization, on both sides of the Lakes, will result in a healthier though much smaller manufacturing sector. The service sector will be expected to pick up the balance of the employment shortfall, especially in key growth sectors, such as tourism and electronics. The resurgence of the research and technology development sector, is of course, linked to the markets for this research and may rebound in the Basin.

Urban sprawl that had slowed down as a result of the recession can be expected to accelerate with the improvement in general economic conditions in both Canada and the USA. Continued loss of natural habitat lands and agricultural lands will continue in pace with urban sprawl. The cessation of migration from the basin and a general return to growth will further serve to deteriorate land use conditions in the Basin.

Pollution prevention has been enthusiastically accepted by many as the preferred approach to environmental management. However, the success of strong voluntary pollution prevention programs is built upon on the sturdy foundation of a sound regulatory framework. Without enforcement of a strong regulatory structure, there is less incentive for companies to implement new pollution prevention activities. The pollution prevention technical assistance providers, housed in regulatory and non-regulatory offices, often find businesses open to voluntary pollution prevention solutions to achieve an environmental end points required by regulations. Businesses also are receptive to the message that pollution prevention will improve their bottom line, benefitting both the economy and the environment. Acceptance of pollution prevention continues.

All of the preceding information relating to SOLEC '94 should be viewed as background for SOLEC '96.

2.0 The Nearshore Ecosystem

The nearshore areas, both aquatic and terrestrial, are the most diverse and productive parts of the Great Lakes ecosystem and at the same time, support the most intense human activity. As a result, the areas that contain the greatest biological resources are subject to the greatest stress. These are the areas most used by humans (and where the majority of humans live - there are 33 million residents living near the lakes) and consequently these are the areas with the most to save and the most to lose.

The Great Lakes basin ecosystem includes the lakes and the entire area draining into them. For the purposes of SOLEC '96 the nearshore land area includes only land that is affected by the presence of the Lakes. The nearshore consists of interactive areas where the lakes influence land and where land directly influences the lakes. The remainder of the basin is important as a source of stressors affecting the nearshore, but is not otherwise the focus of SOLEC '96.

The land by the Great Lakes uniquely and dynamically intersects with life inland and in water. The effects of the Lakes - waves, wind, ice, currents, temperature, and the rising and falling of lake levels - constantly shape the 16,000 km of shoreline. Five hundred river mouths empty into the lakes, each with differing water chemistry and biological components. Rains, snowmelt and winds scour and nourish the land, carrying soils and other materials to the water, then depositing them far away. The ever-changing shoreline, in turn, buffers inland, life-sustaining systems and interacts with coastal marsh systems. It harbours plants and animals adapted to a severe microclimate that suffers frequent and harsh storms, and those that thrive in sheltered areas where the seasonal temperature extremes are moderated by the presence of the lakes. Because of the varied habitats and micro-climates, many rare species and communities are found here.

The extent of the land by the lakes, is defined by the lakes themselves. Wind and wave action shape the beaches, dunes, and shore bluffs, while local climatic effects of large water bodies, exert a huge influence on shoreline habitats and determine the biological communities. These communities, in turn, sustain an amazing diversity of wildlife that enriches the Great Lakes basin.

In terms of water quality, nearshore areas are more varied than the huge masses of relatively stable water in the central areas. This is because the nearshore areas are more affected by waste discharges, land runoff, construction and other human activities. As a result, the quality of nearshore waters varies more from place to place and from time to time. It is also the case that during the spring season shallower water warms faster than deep areas, forming a vertical thermal bar which limits mixing of nearshore waters with the open lake areas until later in the season when surface waters gradually become warmer across the lakes. It is the mixing of water between the nearshore and open lake areas which facilitates the dilution of nearshore pollutants. The dilution example also illustrates the physical linkages which nearshore waters have with adjacent ecosystems, and the exchange of materials and energy which occurs with those ecosystems.

Virtually all species of Great Lakes fish use the nearshore waters for one or more critical life stages or functions. Nearshore waters are areas of permanent residence for some fishes, migratory pathways for anadromous fishes, and temporary feeding or nursery grounds for species from offshore waters. Fish species diversity and production in nearshore waters are higher than in offshore waters. From lake to lake, fish species diversity is generally highest in shallower, more enriched embayments with large tributary systems. Fish may move into tributaries to spawn, then feed and grow in nearshore waters, and spend the winter in offshore waters. Nearshore areas are essential to migratory and resident birds and also for amphibians and mammals as well.

For humans, the nearshore is the area where we: obtain drinking water; boat; swim; fish; build marinas and condominiums; locate industry; and locate sewage treatment facilities.

DEFINITION OF THE TERM
"Nearshore AREAS"

For the purposes of SOLEC '96, the nearshore areas of the Great Lakes are defined in terms of living ecosystems. These are both on land and in the water.

The land areas are those with ecosystems directly affected by the lakes. The water areas are the relatively warm shallow areas near the shores. The nearshore zone also includes coastal wetlands which are dependent on lake levels. In both directions, nearshore areas are generally within 10 miles of shore. Exceptions are in Lake Superior where warm water seldom extends far from shore and in Lake Erie where both the central and western basins are relatively shallow and warm and thus are considered to be "nearshore" in their entirety.

On land, the nearshore zone is that area which is affected by the Lakes - waves, wind, ice, currents, temperature, and the rising and falling of lake levels constantly shape and modify the 16,000 km of shoreline.

In water, the nearshore zone consists of areas with water warm enough to support a community of warm water fish and associated organisms. These areas represent approximately 25% of Lakes Michigan, Huron and Ontario; 90% of Lake Erie; and only 5% of Lake Superior because of its very deep and cold nature. In general these are coastal areas of less than 30 metres in depth except in Lake Superior where they are less than 10 metres in depth. The nearshore waters also include the connecting channels and virtually all of the major embayments of the system.

Beyond the nearshore areas and its lake-associated ecosystems (on land and in water), the SOLEC '96 Impacts of Changing Land Use paper addresses sources of stressors affecting the nearshore areas. These source areas extend upstream far beyond the nearshore area to include virtually the entire Great Lakes basin.

A depiction of the aquatic nearshore is shown in Figure 1.

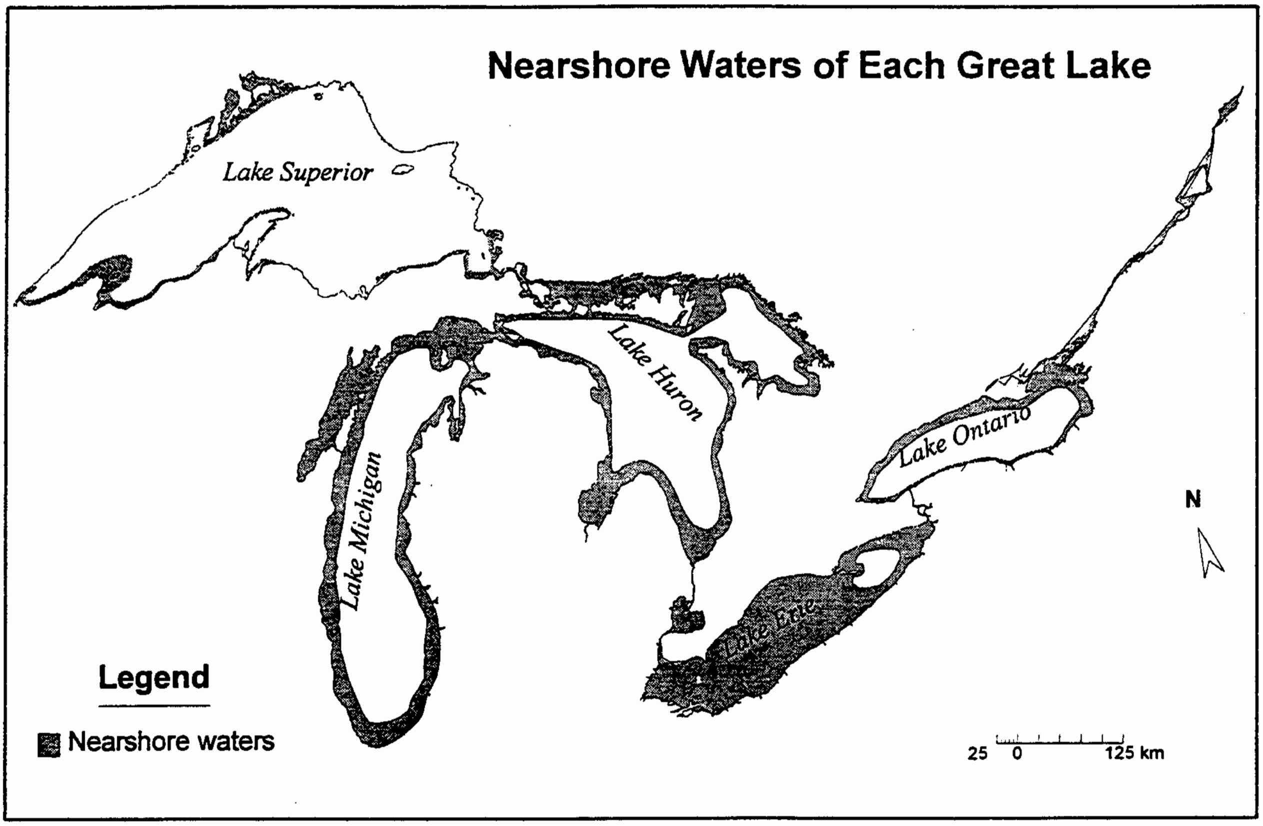


Figure 1. Nearshore Waters

3.0 Biodiversity and Ecosystem Integrity: Saving the Pieces

The state of the lakes can be expressed in many ways, but a fundamental beginning point is the health of the ecosystem in terms of its integrity. The stated purpose of the U.S./Canada Great Lakes Water Quality Agreement is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem.

3.1 Integrity

Integrity is not specifically defined in the Agreement, but is understood to include the health of the biological populations and interactive communities of the ecosystem, and its ability to withstand stress or adapt to it. Ecosystem integrity includes the health of living things, the ability of systems to self organize, and also the physical and chemical environment needed to support good health. An important part of this is genetic diversity.

An essential concept in dealing with ecosystems is that ecological communities are dynamic and exist within ranges of conditions that occur as the result of natural forces. Communities exist in balance with these natural conditions and their composition changes throughout various states that tend toward stability and increasingly complex interrelationships. When compared to younger communities, mature communities are relatively stable and contain proportionately more organisms that are longer lived. These communities also have more specialized and demanding habitat requirements.

The Great Lakes ecosystem, although subject to natural disturbances, was in a relatively mature and stable state before the arrival of European settlers. Since human exploitation of the fisheries and landscape, stable communities of organisms sensitive to disturbances have become rare. Part of the challenge of protecting the ecosystem is to maintain the full spectrum of ecological communities.

Another important aspect of ecosystem integrity is resiliency and the ability of healthy systems to self organize and recover from stress or disruption. In individual organisms this is known as homeostasis: the tendency to maintain, or the maintenance of, normal, internal stability in an organism by coordinated responses of the organ systems that automatically compensate for environmental chances. Much the same result occurs in ecosystems as a result of interactions between component parts.

3.2 Biodiversity

An important aspect of resiliency is biodiversity. It is the diversity of genetic traits within species and among them that supports the ability of ecosystems to survive and prosper even though challenged by changing conditions. The native species and living communities contain within their genetic makeup the "memory" of thousands of years of conditions which they have survived within the Great Lakes Basin.

Ecosystems are dynamic in time scales measured from minutes to millennia and continue to change and evolve. However, the speed of changes being caused by humans far exceeds the changes which occur naturally and does not allow time for the organisms to adapt or evolve. As a result, human intervention is necessary to ensure that component pieces of our ecosystems are not lost and ecosystem integrity can be restored and maintained.

Much of the Great Lakes basin ecosystem has been permanently altered, but much remains. Although some component parts have been lost, it is still those native plant and other living communities which provide the best opportunity for attaining ecosystem integrity and sustainability. It is true that any miscellaneous degraded assemblage of organisms would probably begin to evolve into new stable communities over tens or hundreds of thousands of years, but not that much time is available. It has been suggested that altered and reorganized ecosystems may be just as healthy as prior systems and that ecosystem outcomes can be selected by managers or public opinion.

This might work if people are willing to wait for thousands of years of adaption and evolution, but until time can be manipulated, the prudent choice appears to be management toward the full range of ecosystems that existed at the time of European settlement, as a general goal.

An important aspect of restoring and maintaining integrity and sustainability is the role of high quality areas which contain viable populations of rare or easily disturbed species and/or communities. This includes protecting habitat necessary for all life stages of all species. Sufficient habitat and biodiversity must be protected to ensure survival in the event of catastrophic change in any one area.

An essential aspect of this is the protection of viable populations and communities that are representative of the full range of nearshore ecosystems throughout the basin. This can not be accomplished by preserving a few ecological zoos containing representative samples. It must include fully functioning ecosystems throughout the basin. Living communities are complexes of hundreds and thousands of species of organisms including microbiological organisms such as bacteria, fungi, nematodes, etc.

Another aspect is the concept of critical habitat. While exact definition or identification of critical habitat remains elusive, the idea is that some habitat is essential for survival of various species and genetic stocks or strains within species. Critical habitat is often associated with reproduction and protection of early life stages, but it applies to all life stages including migration.

3.3 Sustainability

Sustainable development is an important concept which is related to ecosystem integrity. Sustainable development seeks to meet the needs of the present without compromising the ability of future generations to meet their own needs. As a society we are still falling far short of this goal since we continue to deplete our non-renewable resources and spend our ecological "capital" by destroying unique habitats and biodiversity.

Every human society has to solve and continue to solve the basic economic problems of how to produce the goods people need or want and distribute them where and when they are desired. Also, they must do so in such a way that information about the changing conditions feeds back into the economic development process and adjustments are made.

For development to be ecologically sustainable, the knowledge gained from the accumulation of ecological insights concerning the impacts of human activities on health and functioning of ecosystems must feed back into the development process and be used to adjust those activities to protect the health and functioning of ecosystems.

Sustainable development is a direction toward an economy developed by technologies, land use practices, laws and institutions that take account of ecological understanding. The great challenge is how to create ways of life and communities within which humans prosper while our actions renew and restore the natural life support system upon which all life and prosperity depends.

SOLEC '96 focuses on two ecosystem integrity aspects of sustainability: 1) that human use and economic development of the ecosystem should be sustainable in the long term; and 2) the idea that biological communities should be self sustaining with a minimum (or zero) human assistance.

Ecosystem integrity is measured both in terms of biological integrity and in terms of human health. Human health aspects of ecosystem integrity are difficult to assess because of the multiplicity of factors affecting human health. As reported in SOLEC '94, there is some direct evidence of human health effects resulting from exposure to pathogens and to persistent bioaccumulative toxic contaminants, but most human health related information is in the form of exposure to health risks.

3.4 SOLEC '96 Framework

For purposes of SOLEC' 96, the ecosystem is viewed as a three layered system somewhat as shown in Table 1 and Figure 2. The highest level of system integrity is measured at the level of ecological and human health. The second level is that of the physical, chemical and biological environment which can also be thought of as habitat. Within the environment are many factors which may be necessary for health or may be stressors which adversely affect health. In many cases a factor may be necessary for ecosystem health, but may become a stressor when present in excessive amounts. The third level of the system consists of the sources of stressors, nearly all of which are the result of human activity. An underlying fourth layer can also be envisioned which would be factors that stimulate or limit stressors. The fourth layer would also include programs for control and remediation which are beyond the purview of SOLEC '96. SOLEC '96 addresses the state of the ecosystem, not the state of programs created to deal with stresses. Such programs are the subject of other conferences and reports.

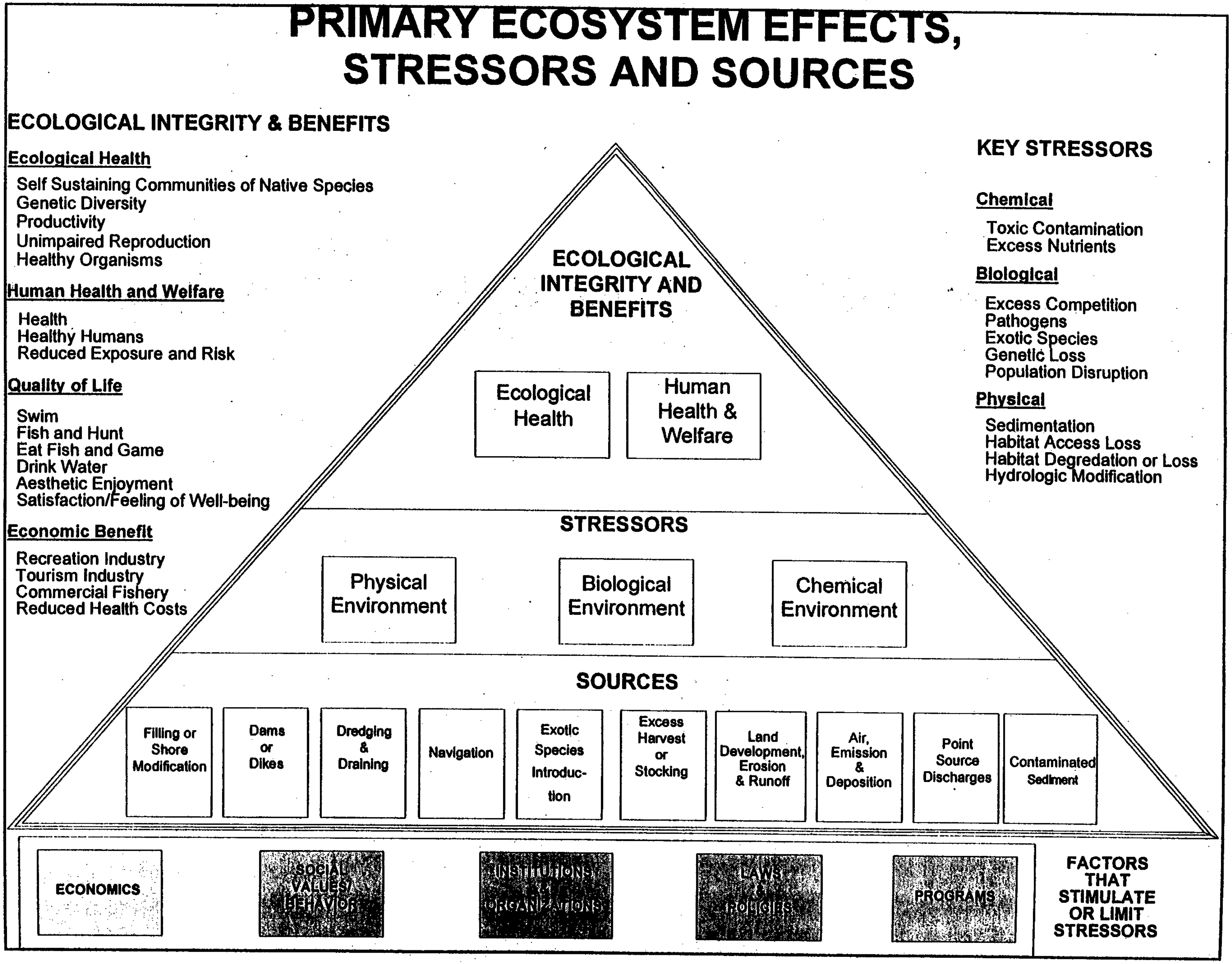
By viewing the state of the Great Lakes ecosystem in the three layers of health, habitat, and stressors, it is easier visualize cause effect relationships and to organize discussion.

Table 1. Three Layered System

ECOSYSTEM INTEGRITY & SUSTAINABILITY (1)	STRESSORS (2)	SOURCES (3)
Ecosystem Integrity/Health • Self Sustaining Communities of Indigenous Species • Ecological Balance • Genetic Diversity • Productivity • Unimpaired Reproduction • Healthy Organisms **Human Health** • Reduced Illness (Including absence of endocrine effects) • Reduced Exposure to Risk **Human Welfare** • Quality of Life Swim Fish and Hunt Eat Fish and Game Drink Water Aesthetic Enjoyment Satisfaction/Feeling of Well-being • Economic Benefit Recreation Industry Tourism Industry Commercial Fishery Reduced Health Cost	**Physical Stressors** • Turbidity • Sedimentation/Burial • Loss of Beach Nourishment • Sunlight Deprivation • Loss of Access to Habitat • Changes in Lake Levels • Changes in Groundwater Levels • Changes in Stream Flow (Volume or timing) • Loss of shelter or substrate **Biological** • Pathogens/Parasites • Genetic Loss • Predator Loss or Excess • Lack of Food/Prey • Lack of Seed/Breeding Stock **Chemical** • Nutrient Excess or Lack • Contaminants	**Land Use** (Includes urban, recreational and agriculture) (4) • Land filling or Shore Modification • Land Clearing • Dredging • Stream Channelization • Urban Storm Drains • Dams and Dikes • Point Source Discharges of Pollution • Nonpoint Sources of Pollution • Contaminated Sediment • Airborne Discharge and Deposition **Exotic Species** **Navigation** **Excess Harvest or Stocking**

(1) Can also be thought of in terms of impacts or impairments of integrity.
(2) Changes in environmental conditions beyond "natural" changes which would occur in the absence of human activity.
(3) Primarily categories of human activities, not individual sources or underlying institutional, social or economic factors)
(4) Land Use includes three main categories of development: urban sprawl; recreational development (summer homes, marinas, etc.); and agriculture/forestry.

Figure 2. Key Stressors of the Nearshore Ecosystem



In examining the state of the Lakes it is useful to ask questions with respect to the three layers:

- What is the state of biological health including humans?
- What is the state of habitat (physical, chemical and biological environment) with respect to presence of factors which are needed by, or are stressors upon, various life forms including humans?
- What is the state of the sources of major stressors and is sufficient progress being made in dealing with them?

To answer these questions it is useful to think in terms of indicators of the state of each of the three levels. This is the subject of the next section.

4.0 Indicators

The purpose of indicators is to provide simple, brief expression of the state of the ecosystem based upon aspects of the system that can be measured and accepted as characterizing its condition. Such indicators can cover various levels of the health of the ecosystem including biological health, stressors, sources, and programs to address problems at all levels.

The health of the living components of the ecosystem, including humans, is the ultimate indicator which reflects the total effect of stresses on the system. The ecosystem effects of stress is often expressed as impairments and are the most meaningful indicators as far as most people are concerned, i.e. is the system healthy and can we swim, fish, eat the fish and drink the water? Although effects on the living system are the ultimate indicators, measures of the physical, chemical and biological stressors and sources that affect the system are equally important in describing the state of the Lakes and providing vital information for programs that address stressors and sources.

Indicators are used to measure the state of living components in terms of both ecosystem health and human health, although human health is most often measured in terms of risk rather than direct health effects.

For the nearshore areas of the Great Lakes there are no widely accepted or generally available indicators that can be used to summarize the state of the ecosystem. As a consequence, the authors of the background papers have developed indicators to the best of their ability. In addition, the SOLEC '96 steering committee has added indicators where necessary. All are based to some extent upon data, but the evaluation and rating assigned are primarily best professional judgement by knowledgeable people. It is hoped that further development of indicators will be stimulated by this effort.

For purposes of simplification, a small number of indicators for each of the background papers has been chosen and are shown in this paper. These simple indicators are intended to summarize the state of the ecosystem and progress being made in addressing the many stressors and their sources.

For a description of the indicators used in evaluating the state of nearshore waters, land by the lakes, wetlands, and information management, please refer to sections 6, 7, and 8.

5.0 State of Nearshore Ecosystem Health

The state of the nearshore areas of the Great Lakes varies from near pristine in parts of the Lake Superior basin to severely impacted throughout much of the Lower Lakes. Historically, the nearshore ecosystem suffered extensive loss and decline primarily due to physical, chemical and biological factors associated with urbanization and farming during the past two centuries. Cause for encouragement can be found in the progress made in controlling chemical problems during the past two decades. Pollution control in recent years has resulted in decreasing concentrations of nutrients and most toxic contaminants in the system. However, as more is learned about the chronic effects of some bioaccumulative contaminants, concern continues. This is particularly the case with respect to possible impacts on reproduction of wildlife and humans.

Unfortunately, physical and biological factors continue to adversely impact the nearshore ecosystem primarily due to intensifying use of land and the spread of exotic species both on land and in aquatic systems. Some progress has been made in protecting wetlands, but irrevocable losses continue in both geographic extent and in genetic diversity. The following is a summary of some of the information to be found in the SOLEC '96 background papers. For additional information on impacts on aquatic communities, the reader may wish to review the 1994 SOLEC paper Aquatic Community Health of the Great Lakes.

In addition to changes in the nearshore areas being directly caused by human activities, the areas are also being degraded because human activities are disrupting natural processes and preventing the normal changes which would otherwise occur. The nearshore is normally a dynamic area with physical forces of wave action, currents and water level changes which cause continuous change in shorelines and biological communities. Alteration of these forces and processes can have major impacts.

The overall rating of the nearshore situation in 1996 is mixed, with some indicators rated as good, while others are rated as poor. Some trends are system wide, but conditions also differ substantially from lake to lake.

5.1 Nearshore Waters

There is little doubt that the nearshore aquatic environment of the Great Lakes has been altered physically, chemically, and biologically by human activity. About 25 years ago however, with the signing of the Great Lakes Water Quality Agreement, society began to act, and the trend to worsening conditions began to slow down and in the case of water quality, to improve. Some problem areas of contaminated sediment remain. Also, persistent bioaccumulative contaminants remain at levels which may be causing problems. Some habitat loss is permanent and habitat losses continue as do losses in biodiversity. Continued vigilance is needed to prevent repetition of past problems.

5.1.1 Areas Within the Nearshore

Tributaries Tributaries deliver nutrients and warm water to the nearshore areas as well as providing rich nearby habitat. The principal spawning and nursery habitats for one third of Great Lakes fishes are located in the tributaries. Flood plains also enhance productivity and maintain diversity. At low water levels, nutrients are mineralized and accumulate; during flooding, nutrients are dissolved and high primary production and decomposition rates occur. The resulting conditions are optimum for spawning and nursery for many species of fish.

Connecting Channels The Great Lakes connecting channels are also important spawning and nursery habitats. While researchers have captured 21 species of fish larvae in the St. Clair River proper, close to three times that number (60 species) have been found in waters connected and adjacent to the river. Young-of-the-year of 48 species were caught in tributaries of the St. Clair River, while larvae of 33 species and juveniles of 27 others have been reported from Munuscong Bay on the St. Mary's River.

Embayments Embayments represent another kind of diverse and sheltered habitat for fish species in nearshore areas. Although many embayments contain wetlands, they also include areas of open water. Often, an embayment is an area of transition between open water and riverine habitats.

Exposed Coastline and Offshore Shoals Although total fish numbers are generally lower in sheltered habitats, these areas present unique features optimum for certain species, particularly those adapted to turbulent environments. Offshore shoals are spawning habitats for some species and feeding areas for aquatic birds. Coastal upwellings also provides cold water species periodic access to shallow littoral habitats.

Temperature Temperature is a key attribute of the Nearshore. It controls growth, reproduction, and survival of fishes and other aquatic biota, and can regulate food supplies, competition, and predation. For species near the northern limit of their range, the availability of sheltered shallow habitats, which warm early in spring, is essential for survival. For other species, using warmer nearshore areas effectively increases the growing season and may significantly increase production.

5.1.2 State of the Resource

Vegetation - Algae and Macrophytes 77 out of 133 young-of-the-year fish species examined are moderately to strongly associated with aquatic vegetation; more species are associated with submergent than emergent vegetation. Wetlands provide critical spawning and nursery habitats for many fish species; several authors reported high species richness of young fishes from wetland habitats.

Phosphorus and nitrogen, nutrients important to algal growth are added to lakes in the nearshore zone through land runoff from farms and urban areas, sewage treatment plants and combined sewer overflows.

Data from recent sampling indicated elevated concentrations of phosphorus and nitrate-plus-nitrite, as well as the highest concentrations of chlorophyll a, were observed in inshore waters. In Lake Ontario, where the spring phosphorus guideline is 0.010 ppm, excess levels are observed at "nearshore" stations. Similarly, in Lake Erie, where the total phosphorus guideline is basin-specific (0.015 ppm for the Western Basin, 0.010 ppm for the Central and Eastern Basins), exceedances are also observed, both at stations that meet the "nearshore" criteria, and offshore.

An overabundance of nutrients leads to nuisance algal populations in the water and algae attached to rocks and structures. Macrophytes depending on nutrients stored in sediment may cause navigation problems for recreational boaters in shallow water areas.

Long term chlorophyll data reflect the results of phosphorus control programs. After 1988-89 in Lake Erie there was a further reduction attributed to the establishment of zebra/quagga mussels and to their filtering of algae and deposition of wastes on the lake bottom. A reduction of 30-50% at the Grand Bend location in 1993-94 is consistent with the delayed establishment of mussels in parts of Lake Huron. Similarly, large recent reductions in chlorophyll at Kingston and Brockville followed the establishment of mussels in eastern Lake Ontario and the Bay of Quinte in 1992-94.

In a short while (10 years), the zebra mussel impacts on Lake Erie planktonic algae have been dramatic in all three basins. In the western basin, however, a longer term view of the data (30 years) provides a very different perspective relative to the phosphorus loading control effects. Over that period, declines in chlorophytic plankton, including several "weedy" species due to phosphorus control were of greater importance than the decline experienced in 1988 attributable to zebra mussels.

Zooplankton Zooplankton are important parts of aquatic food webs, filtering and eating algae and then providing energy and nutrients for fish. Populations of zooplankton cycle seasonally in response to temperature and food availability, as well as predation by fish. In the western basin of Lake Erie, since the late 1920s, zooplankton increased with eutrophication and then declined as nutrient loading was controlled. Recently, an exotic species the spiny water flea *Bythotrephes,* has appeared, disrupting zooplankton populations.

To some extent, the challenges to the zooplankton community seen in the lower lakes are present in all lakes. In the last 13 years introduced species have changed energy flows in the lakes so that expectations of fish yield based on previous trophic structure may not be realized.

Benthic Invertebrates Dramatic changes in the community structure of benthic invertebrates have occurred over broad areas in the nearshore zone. These changes have been attributed to changes in water and sediment quality resulting from nutrient and other pollution abatement programs, and to ecological changes caused by the zebra mussel.

The increase in abundance and distribution of the burrowing mayfly provides dramatic evidence of improved conditions in the western basin of Lake Erie. This organism was historically abundant in the western basin, but a gradual increase in productivity of the basin over time, along with a period of calm weather in the mid 1950s resulted in a severe decline in oxygen concentrations that virtually eliminated the population. A small increase in the population was noted near the mouth of the Detroit River in 1980, but it was not until 1991 that the population increased to any major extent. By 1995, burrowing mayflies were found throughout the western half of the basin and in much of the eastern half.

Fish The native fish fauna of the Great Lakes basin comprises 153 species in 64 genera and 25 families and is relatively large and diverse. Status and trend information are available for a number of fishes commonly found in the Great Lakes.

The lake sturgeon, which does not reproduce until it is about 25 years old, was one of the first species to approach extinction in the Great Lakes. The blue pike, a high-value species that reproduced at about four years of age, became extinct by overfishing. The walleye, a closely related species, was also severely overfished in Lake Erie. Catches declined from highs of about 2.3-2.8 million kg annually in the late 1940s-late 1950s to about 25,000 kg in 1971.Closure of the fishery due to mercury contamination in the early 1970s followed by the imposition of more stringent catch regulations allowed walleye numbers to rapidly increase and the species again supports a healthy, self-sustaining, high-value fishery.

High-value cold water fishes that use the nearshore waters during the colder months of the year declined to virtual extinction in all or some of the Great Lakes; these species include the lake trout, lake whitefish, and lake herring. Native populations of lake trout were nearly extinguished in the Great Lakes as a combined result of overfishing, predation by the introduced sea lamprey and impaired reproduction, possibly the result of bioaccumulative persistent toxic substances. Lake whitefish populations reached record lows in the 1950-1960s in Lake Huron, and the 1950s in Lake Michigan but have since recovered.

The loss of native genetic diversity affects the status of the Great Lakes ecosystem irreversibly. Habitats, particularly those in deep water, that were occupied productively by native species and stocks that had become adapted to them following the retreat of the glaciers from the basin about 10,000 years ago, were left unoccupied. Other vacated habitats in shallower water were left open to invasion by undesirable exotic species that had gained access to the basin as a result of human activities.

In Lake Superior, lake trout are presently maintained by stocking and natural reproduction of wild fish. Brook trout and lake sturgeon populations have not recovered from earlier declines. Lake herring are recovering strongly, but the introduced rainbow smelt has not recovered to earlier levels of peak abundance. Lake whitefish are abundant; sea lamprey has been reduced to about 10% of its former peak abundance; ruffe are increasing in abundance.

In Lake Huron, the fish community is recovering, but is unstable after decades of over harvest and the effects of introduced species. Some lake trout are reproducing ; whitefish are more abundant than at any other time in the century. Walleye and yellow perch are once again abundant. In the 1980s, the sea lamprey increased in abundance in the northern end of the lake, causing continuing high mortality and reversing recent gains in lake trout restoration in that area.

In Lake Michigan, large numbers of stocked, breeding-age lake trout are present in lake trout refuges. Pacific salmon abundance is sharply reduced since the 1970s. Numbers of adult Pacific salmon deaths are correlated with the incidence of the introduced pathogen that causes bacterial kidney disease. Alewives were more than 80% of the biomass in catches in the 1970s but declined to about 10% in the mid-1980s-1990s. The biomass of rainbow smelt decreased from 15-20% in the 1970s to less than 10% in the mid-1980s and 1990s. Slimy sculpin abundance peaked in the late 1970s, but in the 1980s-1990s declined to less than 20% of peak 1970s levels, probably in response to predation by trout, salmon, and burbot.

In Lake Erie fish populations have improved, but continue to change. Lake trout restoration goals are being met and lake whitefish are recovering. Walleye and yellow perch are intensively managed to provide productive recreational and commercial fisheries in the United States and Canada. Abundance of major forage fish species such as rainbow smelt, spottail shiners, emerald shiners, gizzard shad, and alewives, may be declining.

Fish from nearshore waters in areas of contaminated sediment sometimes have harmless or cancerous tumours. Tumour production may be a response to degraded habitat. Tumour outbreaks have been found in populations of benthic species, including brown bullhead, white sucker, common carp, bowfin, and freshwater drum. Of white suckers sampled from nine Areas of Concern, 5.3% had liver tumours. Incidence of liver tumours in white suckers is associated with exposure to carcinogenic contaminants; tumour prevalence of 5% or greater is an indication of such exposure.

Bullhead from the Cuyahoga and Detroit rivers had tumour prevalence of 8-10%, and those from the Buffalo River and Presque Isle Bay, about 20%. These river systems have elevated levels of polynuclear aromatic hydrocarbons (PAH) in some sediment. In 1982, when a coking facility on the Black River (Ohio) was operational, the bullhead population had a liver cancer prevalence of 38.5% .The coking facility closed in I983. By I987, PAH concentrations in surficial river sediment had declined to 0.4% of the concentration in 1980, and the cancer frequency in the bullhead population also declined to about one-fourth of that for I982. Areas of sediment most contaminated with PAH were dredged in 1990, and two years later the cancer incidence in bullhead exceeded that in 1982. This case history shows that natural, unassisted remediation can be effective in reducing the incidence of cancer in bullheads in some systems, and that dredging with traditional methods can temporarily increase cancer incidence and degradation of the health of native species. Collectively, these data show that bullhead liver tumours track PAH levels in natural systems, making tumours a good biomarker for exposure of benthic fish to carcinogens in sediment.

In Lake Ontario, the fish community has improved considerably from the low point of the 1960s. For example, lake whitefish, typically most abundant in the eastern end of the lake, were nearly absent in the 1970s, began increasing in 1980s, and are now 30-40-fold more abundant. In addition, lake trout have finally begun to reproduce naturally in Lake Ontario, after an absence of natural reproduction of some 45 years.

Birds Nearshore waters are used periodically by a variety of waterfowl, from late summer until migratory flights the following spring. Dabbling ducks begin to use areas next to coastal wetlands for resting and refuge in August and September. Sites with open water in winter are important for mallards as resting areas.

The nearshore is an important area for migrating and staging waterfowl, especially diving and sea ducks. In spring and autumn, some sites are internationally important for Tundra Swans, Canvasbacks, Redheads, Greater and Lesser Scaup, Common

Goldeneye and Common and Red-breasted Mergansers. Birds use the nearshore most in autumn but flocks are more concentrated in the spring due to less open water. These sites, where ice thaws first and, presumably, food is first available, may be more critical or limiting in the spring.

Lesser scaup appear to be responding to abundant supplies of zebra mussels. If this trend continues, an increased use of nearshore waters during the October-November and March-April periods can be expected.

Islands, most of which occur in water less than 30 m deep provide nesting habitat for many species of aquatic birds. These include species of colonially nesting gulls, terns, herons, cormorants, as well as species of waterfowl, two species of aquatic raptors and several species of reptiles and amphibians.

Ospreys and Bald Eagles are two aquatic raptors which historically nested along the shoreline of the Great Lakes and on offshore islands. On Lake Erie only the eagle has re-colonized the shoreline (mainland) sites. Neither species has returned to nest on islands, and there are no eagles or ospreys nesting on Lake Ontario, although suitable habitat exists on mainland and islands.

Most species waterbirds are absent from the Great Lakes during winter, having migrated in September and October. Adult Herring Gulls remain, but Great Black-backed Gulls immigrate from the Atlantic; several species come from the Arctic. Most Ring-billed Gulls also leave. For over-wintering gulls, the Niagara River is the major staging and congregating area. Large numbers of fish provide excellent feeding habitat for gulls in this area.

Bald eagles over-winter along the St. Lawrence River from Gananoque to Mallorytown, Ontario, an area open for most of the winter. The eagles feed on ducks and deer carcasses, most of the latter being intentionally provided by man.

Mammals Otter, mink, beaver, muskrats, and raccoon occur in sheltered parts of the system including embayments, tributaries, and connecting channels. Larger mammals including deer, moose, wolves, and coyotes, use the ice bridges in nearshore waters as migration routes.

5.1.2.1 Human Health

Infectious Organisms as Health Hazards During this century, water-borne infectious illnesses became rare in the Great Lakes basin, with effective treatment of drinking water and sewage, and because of immunization programs. However, even modern water treatment plants have weaknesses. In 1993 about 400,000 inhabitants of

Milwaukee became infected, and about 4,000 were hospitalized, by a protozoan parasite (*Cryptosporidium*).

Some sewage treatment plant discharges are not disinfected before release, especially during storm flows, and thus contribute to the pathogen load of nearshore waters. In addition, some sewage plant effluents, especially those carrying industrial wastes, are toxic to algae and probably also to other aquatic organisms. Other effluents such as urban stormwater and agricultural runoff also contain pathogens and toxic chemicals . The chemical disinfectants used to kill pathogens in sewage and in drinking water also can create toxic byproducts. In densely settled and heavily used areas, the numbers and kinds of toxic chemicals found even in treated waters can be considerable. The leaching of components of the materials used for water distribution and storage systems can further contribute to the mix of chemicals in water.

Beach Closures Although improved sewage treatment and nutrient control has made beach closings far less common than in the past, they remain a problem in some urban areas. Closings are an indicator of problem conditions, but it is important to recognize that information on closings does not represent a consistent set of data. There is no standard rule for deciding when to close a beach nor is there a requirement that beaches be monitored. As a result., some problem situations may not be recognized or reported. Nonetheless, available information is of interest.

In 1981-94, 42 of 83 counties reported they had no beach closings due to pollution. Beach closings in the other 41 counties varied widely. Only 2 of 15 counties bordering Lake Superior reported pollution problems; similarly, 17 of 33 on Lake Michigan, 6 of 13 on Lake Huron, 2 of 2 on Lake St. Clair, 11 of 13 on Lake Erie, and 4 of 8 on Lake Ontario reported closings. Generally closings were fewer in northern counties where human population density was low and there was little industrial development; conversely, more closings occurred in southern counties where the shoreline was more intensively developed, population density was high, and there was extensive industrial development.

Drinking Water Treated and tap waters usually meet microbiological standards and objectives; while chlorination led to increased concentrations of chloroform and other chlorination byproducts in tap water, treatment also reduced bacteria numbers essentially to zero for *Escherichia coli* and coliforms.

Nevertheless there is a need for further studies to clarify regional and seasonal variations in the levels of water disinfection byproducts.

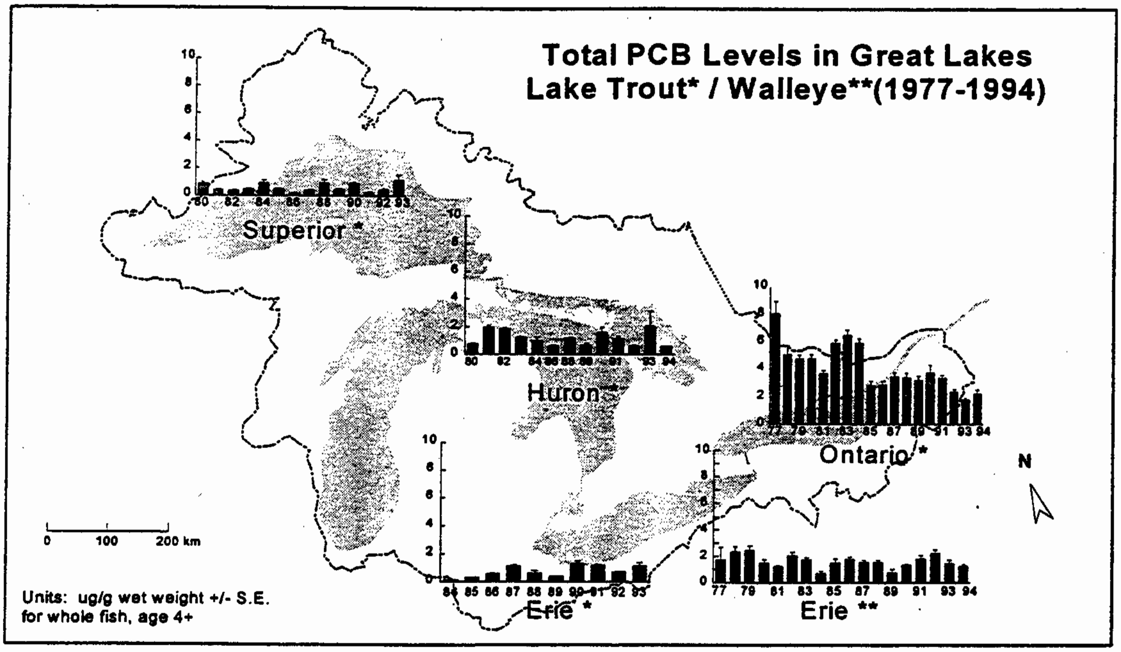


Figure 3. Trends in contaminant concentrations in lake trout and walleye

Fish Consumption Advisories Consumption of contaminated sport fish and wildlife can significantly increase human exposure to Great Lakes pollutants. Fish from contaminated sites may contain high levels of toxic bioaccumulating contaminants, and may show elevated levels of abnormalities, including tumours . Therefore both provincial and state governments have issued sportfish consumption guidelines.

Recent studies show an association between the consumption of contaminated Great Lakes fish and body burdens of persistent toxic substances, including PCBs, other organochlorines, heavy metals such as mercury and lead, and PAHs. Fish eaters may have three- to four-fold higher levels of contaminants than those in the general population.

Trends in contaminant concentrations in lake trout and walleye versus time are plotted in Figure 3. Generally there has been a decline in levels from those seen in the early 70's, but recently, there has not been any further decline. Further information on contaminants is available in the 1994 SOLEC paper Toxic Contaminants.

Smog The Great Lakes basin contributes to air quality problems because of the industrial and urban development around the lower Great Lakes. Local concentrations of ground-level ozone and acid aerosols can be significantly elevated over what is observed at sites well inland from the shores.

Ground-level ozone deposits poorly on lake waters, so that it travels further than would otherwise be the case. On the other hand, the ammonia which normally neutralizes acid aerosols dissolves well so that such aerosols persist longer in the acid state. The Great Lakes also develop local lake breeze circulations, which can confine pollutants and under the right conditions cycle them around the lake shorelines . This limits dispersion and creates something of a "pressure cooker" in which greater concentrations of smog can form in urban plumes (e.g. Chicago).

In Ontario, the highest concentrations of ground-level ozone are measured at Long Point on the Lake Erie shoreline, followed by stations near Lake Huron. There is a similar pattern around all of the Great Lakes south of Lake Superior. During smog episodes, acid sulphate concentrations have been measured near Lake Erie which were more than twice that observed inland. Ozone levels were high as well.

This local pollution 'enhancement' mechanism is due to the very existence of the lakes and cannot be changed. Abatement measures designed for inland sites may not be sufficient near the shores or over the lakes.

Further, the potential health impacts need to be properly assessed and communicated to the public. We may have to advise citizens that the summer air on that Lake Erie beach or in other recreational areas is worse than it would be in the city, considering the impacts of the total pollution load.

Climate Change- A potential human health concern A higher rate of mortality can be expected due to heat stress as climate changes (similar to those experienced in Toronto and Chicago in 1995). Climatic conditions may change sufficiently to allow the spread of vector-borne diseases such as malaria and Lyme disease into Ontario unless strong public health measures are introduced. Changes in weather stability may alter the frequency, severity and duration of extreme events such as severe storms, wildfires, droughts, floods, landslides, and coastal erosion and add to suffering and loss of life.

Fatalities and respiratory and cardiovascular illnesses attributed to severe air quality incidents are likely to worsen in a $2xCO_2$ climate. The young, the elderly and those with respiratory ailments are particularly vulnerable. The frequency of high ground level ozone pollution episodes is likely to increase with "heat waves".

5.1.2.2 Evaluation of the State of Nearshore Waters

Indicators for nearshore waters (Table 2) were developed under the four broad categories, within which are individual indicators. These categories and indicators are consistent with the International Joint Commission's recent report on proposed indicators.

Table 2. Indicators of Ecosystem Health for Nearshore Waters

Desired Outcome	Indicators	Rating
Healthy human populations	Fish consumption advisories	Mixed/improving
	Beach closings, measured in median number of consecutive days closed for a given year	Inadequate data
	Drinking water purity	Good
	Acute human illness associated with locally high levels of contaminants and/or Chronic human illness associated with long-term exposure to low levels of contaminants	Inadequate data Inadequate data
Healthy fish and wildlife	Status of exotic species	Poor
	Status of native species and their habitats	Mixed/improving
Virtual elimination of persistent toxic substances	Levels of persistent toxic chemicals	Mixed/improving
	Concentrations of persistent toxic substances in biota	Mixed/improving
Absence of excess nutrient loading, leading to cultural eutrophication	Dissolved oxygen depletion of bottom waters	Good
	Water clarity/algae blooms	Mixed/improving

5.2 Coastal Wetlands

The state of coastal wetlands in the Great Lakes ecosystem are known only in part. There is no inventory or evaluation system in place for the majority of coastal wetlands. Much is known about the stressors that degrade wetlands and some local areas have been relatively well studied as to their condition, but it is not possible at this time to provide a comprehensive review of the state of Great Lakes coastal wetlands.

The general location of coastal wetlands is known from remote sensing and aerial photography, but there is no commonly accepted system of classification nor is there systematic information on their quality, rate of loss or rate of degradation.

Aspects of wetlands that could be used in developing indicators relate to both ecological quality and stressors. Quality measures include various aspects of structure and function, species richness, disturbance sensitive species, disturbance tolerant species, growth rates and form. The diversity and abundance of aquatic invertebrate, fish and wildlife communities have also been used, as have population survival and mortality. Measures of stressors have also been developed ranging from visual change over time to measures of invasive plants and fish, turbidity, sedimentation, water level, and pollutants. Sources of stressors can also be measured in the form of shore modification, land use changes, removal of vegetation, road construction, etc. All of these measures could be developed into a system of indicators, but they have not as yet. For a further discussion of potential indicators, please refer to the wetlands paper.

Wetlands are generally defined as land that is saturated with water long enough to promote aquatic processes as indicated by poorly drained soils, water-loving vegetation, and various kinds of biological activity adapted to wet environments.

Names for various kinds of wetlands differ in the U.S. and Canada, but the general categories for coastal wetlands are marshes, swamps and peatlands. Marshes are periodically or continually flooded wetlands characterized by emergent vegetation that is adapted to living in shallow water or moisture saturated soils. Swamps are wetlands dominated by trees or shrubs with standing water present most or part of the year. Peatlands are wetlands in which plant materials are produced faster than they decay and partially decomposed plant material (peat) accumulates.

Eight types of Great Lakes coastal wetlands can be identified by their morphological setting, which reflects the influence of lake processes, especially exposure to waves. These categories are described in the SOLEC '96 Coastal Wetlands background paper.

Although consistent basin-wide information on the state Great Lakes coastal wetlands is not available as noted above, some general information can be reported on a lake by lake basis .

Relatively few wetlands of the Great Lakes have escaped the impacts of humans. In many respects, the upper lakes have been less affected than the lower lakes. The diversity of Lake Ontario wetlands has suffered as a result of water-level regulation associated with construction and operation of the St. Lawrence Seaway . Unlike site-specific disturbances, this subtle, yet pervasive environmental alteration has affected nearly all wetlands of Lake Ontario. Regulation has also caused greater increases in invasive plants such as purple loosestrife and reed canary grass. Site-specific disturbances in Lake Ontario include extensive shoreline development (especially around large barrier beach wetlands and near larger cities), dredging and filling (especially near harbors, marinas, and waterfront developments), and chemical contamination.

Most of the extensive Great Black Swamp of western Lake Erie has been drained and converted to other land uses, primarily agriculture. Much of the remaining wetland has been diked for intensive management and is hydrologically isolated from the lake. The innovative Metzger Marsh Restoration Project seeks to develop means to allow diked wetlands to be reconnected with the lake and restore multiple wetland functions. Extensive use of revetments to protect shoreline property from erosion has limited the supply of sediments in the littoral drift of western Lake Erie. The few remaining natural wetlands that were once protected by barrier beaches and sand spits are thus losing their protection as losses to erosion cannot be replenished. Examples include Cedar Point in Ohio and Woodtick Peninsula in Michigan. As with Lake Ontario, site-specific disturbances occur also.

The deltaic marshes of Lake St. Clair are intact in many places, but shoreline development, dredging, and placement of dredge spoils have taken their toll. Many of the wetlands on the Canadian side have been diked for management. Increased water clarity in Lake St. Clair resulting from the filtration activities of zebra mussels has dramatically increased the extent of submersed aquatic vegetation in much of the lake.

In the upper Lakes, some extensive wetlands still remain, such as those of Saginaw Bay in Lake Huron. However, much of the Saginaw Bay region resembles western Lake Erie in having been drained and converted to farmland. Chemical contamination and physical disturbance from human activities are also a concern.

Northern Lake Michigan has numerous wetlands, many in ridge and swale formations that developed as lake levels dropped over the last 4000 years and many in drowned river mouths. Watershed activities such as logging and agriculture have affected these wetlands. Hydrology of most drowned-river-mouth wetlands has been altered by road construction across the wetland and, in many cases, by upriver dams. Industrial and municipal development has altered large areas of wetland at the lower reaches of these river systems; landfills and chemical contamination of sediments are included among the impacts. Green Bay in western Lake Michigan has a storied history of abuse that has been detailed by Harris et al.

Wetlands of Lake Superior have probably been affected to some extent by water-level regulation associated with the locks at Sault Ste. Marie. However, as the uppermost lake in the system and with more natural water-level management, the effects are not as striking as in Lake Ontario. Alterations of Lake Superior wetlands include site-specific activities such as harbor and marina development, shoreline development, road construction, and chemical contamination, as well as watershed impacts, especially from logging activity. However, comparatively, wetlands of Lake Superior are probably less affected by human activities than those of the other lakes. Site-by-site evaluations of Great Lakes wetlands within the state of Michigan (lakes Superior, Huron, Michigan, St. Clair, and Erie) have been reported by Albert.

5.2.1 Ecological Processes

Great Lakes coastal wetlands are complex ecosystems. Climatic factors drive many of the basic physical and biological cycles in wetlands, but wetlands are also heavily influenced by water level fluctuations, both short term long term, as well as diking of wetlands, modification of shorelines and many other influences. Longer term water level fluctuations are very important for coastal wetlands. Differences between recorded all time high and low water levels range from 1.1 m to 1.8 m depending on the lake (International Joint Commission, 1989). These changes have profound impacts on the wetland plant communities, causing landward or lakeward shifting of vegetation communities. As discussed in the coastal wetlands paper, and in this paper in the section on stressors, human regulation of lake levels is the most pervasive stressor of Great Lakes coastal wetlands.

In many cases, individual wetlands have unique ecosystem conditions and, thus, cannot easily be compared to one another.

Common ecological characteristics shared by coastal wetlands, in terms of nutrient dynamics, include: temperate; climate; nutrient regimes closely linked with hydrologic regimes; highly productive macrophyte and phytoplankton communities supporting large populations of bacteria and zooplankton; and relatively shallow water, so that exchange between the water column and sediments is rapid.

5.2.2 Ecological Functions and Values

Most wetlands provide some combination of the following functions:

food conveyance and storage; sediment control; water quality improvement; water, food, and timber supplies; recreation; aesthetics; open spaces; history; education; research opportunities; barriers to waves and erosion; and biodiversity through habitat for fish, shellfish, waterfowl, wildlife, and for rare species.

The habitat value of coastal wetlands include both conditions for vegetative and animal communities at all levels of the food web. At the lower end of the food web wetlands provide habitat for innumerable microbes, invertebrates, and shellfish. Reptiles and amphibians are commonly found in wetlands for at least part of their lifecycle and a large number of fish species require wetland habitat for spawning, feeding, or shelter. Birds are attracted to wetlands by abundant food sources and sites for nesting, resting and feeding.

With respect to rare, threatened or endangered species, wetlands provide for many of them, some of which are rare for the reason that so little wetland area remains undisturbed. About one fourth of plant species, one half of fish species, two thirds of birds and three-fourths of amphibians listed as threatened or endangered in the U.S. are associated with wetland.

An assessment of the state of wetlands, based on four desired outcomes and eleven indicators is presented in Table 3.

5.3 The Land by the Lakes

The land by the Great Lakes uniquely and dynamically intersects with life inland and with life in water. The effects of the Lakes - waves, wind, ice, currents, temperature, and the rising and falling of lake levels - constantly shape the 16,000 km of shoreline. Five hundred river mouths empty into the lakes, each with differing water chemistry and biological components. Rains, snowmelt and winds scour and nourish the land, carrying soils and other materials to the water, then depositing them far away. The ever-changing shoreline, in turn, buffers inland, life-sustaining systems and interacts with coastal marsh systems. It harbors plants and animals adapted to a severe microclimate that suffers frequent and harsh storms, and those that thrive in sheltered areas where the seasonal temperature extremes are moderated by the presence of the lakes.

Table 3. Indicators of Ecosystem Health for Coastal Wetlands

Desired Outcome	Indicators	Rating
Preservation of wetland area	Land-use changes, encroachment /development basin-wide	Poor
	Landuse adjacent to wetland	Poor
	Wetland size, abundance	Poor to mixed/deteriorating
	Shoreline modification	Poor to mixed/deteriorating
Wetland quality	Water level fluctuation: Lake Ontario Lake Superior Unregulated Lakes	 Poor Poor to mixed/deteriorating Good
	Protection from erosive forces	Inadequate data
	Levels of persistent toxic chemicals	Mixed/improving
Healthy habitat	Status of plant communities	Mixed/deteriorating
	Status of individual plant species	Mixed/deteriorating
Healthy fish and wildlife	Status of exotic species	Poor
	Concentrations of persistent toxic substances in biota	Mixed/improving

The extent of the land by the lakes, is defined by the lakes themselves. The physical changes caused by wind and wave action that shape the beaches, dunes, and shore bluffs, and the local climatic effects of large water bodies, exert a huge influence on shoreline habitats and determine the biological communities. These communities, in turn, sustain an amazing diversity of wildlife that enriches the Great Lakes basin.

The relationship of nearshore terrestrial ecosystems to other Great Lakes systems is one of interdependence. Nearshore terrestrial ecosystems buffer coastal marsh, lake plain, and inland wetland and terrestrial systems, protecting them from severe wave and wind action generated by the lakes.

5.3.1 Ecosystem Health for the Land by the Lakes

The review of the state of the land by the lakes contained in the SOLEC '96 background paper The Land by the Lakes: Nearshore Terrestrial Ecosystems The paper looks at the nearshore ecosystem as two layers:

5.3.1.1 Coastal Ecoregions

The land by the lakes paper divides nearshore land into 17 geographic coastal ecosystems based upon physiographic and biological features. The coastal ecoregions are shown in Figure 5. Table 4 provides a summary rating for each region and trends within it. The factors used in the evaluation are presented in the working paper.

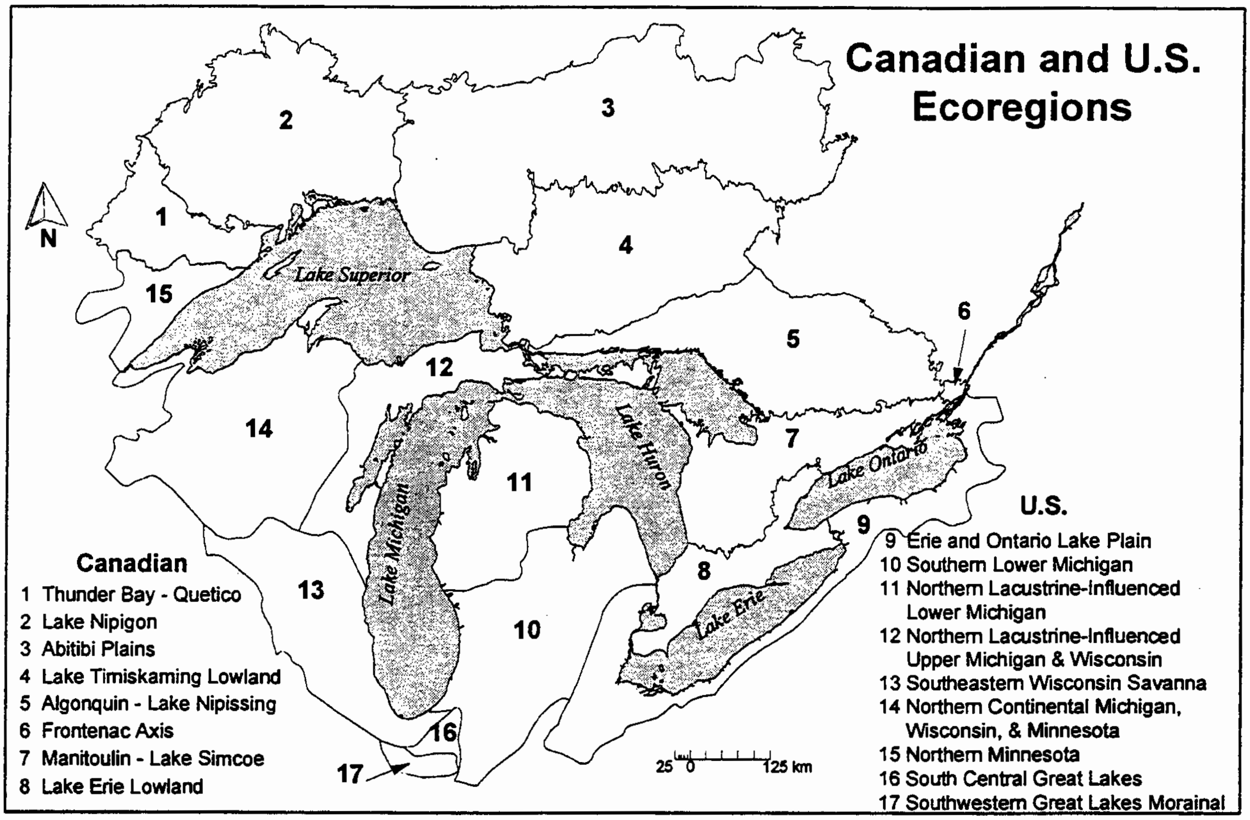


Figure 4. Coastal Ecoregions

5.3.1.2 Special Communities

The land by the lakes paper identifies 12 special nearshore ecological communities which may occur in more than one of the regions. The identity and status of these 12 special communities is summarized in Table 5. The factors used in the evaluation are presented in the working paper.

The quality of the 12 special lakeshore ecological communities is rated based on the percent of the community remaining in a healthy state, major stresses and sources of stress, processes and functions impaired by the stressors, species and communities endangered or threatened, and stewardship activities in place. Within the 17 ecoregions and special communities are hundreds of kinds of living communities which range widely in condition. Reporting on this finer level of detail is beyond SOLEC '96 and is left for others to address.

Table 4. Indicators of Ecosystem Health for Great Lakes Coastal Ecoregions

ECOREGION	RATING	TREND
Thunder Bay–Quetico	C	Moderately Degrading
Lake Nipigon	B	No Change
Abitibi Plains	A	No Change
Lake Timiskaming Lowland	B	No change
Algonquin–Lake Nipissing	B	No Change
Manitoulin–Lake Simcoe	D	Moderate-severely degrading
Lake Erie Lowland	D	Severely degrading
Frontenac Axis	C	Moderately degrading
Erie /Ontario Lake Plain	D	Severely degrading
Southern Lower Michigan	C	Moderately degrading
South Central Great Lakes	C	Severely degrading
Southwestern Great Lakes Morainal	C	Severely degrading
Northern Lacustrine-Influenced Lower Michigan	B	No change
Southeastern Wisconsin Savanna	D	Severe degrading
Northern Lacustrine-Influenced Upper Michigan and Wisconsin	B	Moderately degrading
Northern Continental Michigan, Wisconsin, and Minnesota	B	No change
Northern Minnesota	B	Moderately degrading

Table 5. Indicators of Ecosystem Health for Special Great Lakes Ecological Communities

Ecological Community	Rating	Trend
Sand beach	C	Moderately Degrading
Sand dune	D	Moderately Degrading
Bedrock beach/cobble beach	D	Moderately Degrading
Unconsolidated shore bluff	C	Moderately Degrading
Coastal gneissic rocklands	C	Moderately Degrading
Limestone cliffs/talus slopes	B	Moderately Improving
Lakeplain prairies	F	Severely Degrading
Sand barrens	D	Moderately Degrading
Arctic disjunct communities	B	No Change
Atlantic coastal plain communities	C	Moderately Degrading
Shoreline alvars	F	Severely Degrading
Islands	C	Moderately Degrading

5.3.1.3 Overall Assessment

With respect to an overall lake by lake evaluation of the land by the lakes, four indicators were selected:

1. Loss of significant ecological communities and species.
2. Interruption of shoreline processes by lake edge armouring.
3. Representation of coastal biodiversity within protected and adequately stewarded areas.
4. Gains in biodiversity investment habitats protected through public ownership or policy.

These indicators have been rated as follows, in the table below.

Table 6. Indicators of Overall Ecosystem Health for the Land by the Lakes

INDICATORS	STATUS OF INDICATORS			
	Good	Mixed/ improving	Mixed/ deteriorating	Poor
1. **Lake Superior**				
Loss of shoreline species/communities	*			
Interruption of shoreline processes by armouring	*			
Representation of biodiversity in lakeshore parks and protected areas	*			
Gains in biodiversity investment areas		*		
2. **Lake Michigan**				
Loss of shoreline species/communities			*	
Interruption of shoreline processes by armouring			*	
Representation of biodiversity in lakeshore parks and protected areas			*	
Gains in biodiversity investment areas		*		
3. **Lake Huron**				
Loss of shoreline species/communities			*	
Interruption of shoreline processes by armouring		*		
Representation of biodiversity in lakeshore parks and protected areas		*		
Gains in biodiversity investment areas			*	
4. **Lake Erie**				
Loss of shoreline species/communities			*	
Interruption of shoreline processes by armouring				*
Representation of biodiversity in lakeshore parks and protected areas			*	
Gains in biodiversity investment areas				*
5. **Lake Ontario**				
Loss of shoreline species/communities			*	
Interruption of shoreline processes by armouring				*
Representation of biodiversity in lakeshore parks and protected areas			*	
Gains in biodiversity investment areas			*	

The concept of identifying geographic regions and special resources or communities within them is a powerful approach to reporting the state of the ecosystem. Also, it could be extended to both coastal wetlands and nearshore waters. As a further step, the indicators can serve as a means of obtaining agreement on acceptable conditions. This can set expectations and be extended to setting goals and tracking progress in protection and restoration.

It is the hope of the SOLEC '96 organizers that conference participants will find the systematic reporting developed in the land by the lake paper to be useful and provide feedback for further developing the approach.

For long term use the boundaries of the ecoregions used in the land by the lakes paper need refinement since the they are based upon multiple sources and the regions overlap to some degree.

The overall conclusion is that the health of the land by the lakes, nearshore terrestrial system is degrading throughout the Great Lakes basin. To address this situation it is concluded that a conservation strategy for Great Lakes coastal areas is urgently needed which would involve all levels of government, reflect commitments to conservation of biodiversity and sustainable development and secure broad support from citizens of the basin. It is further concluded that the most effective approach would be to place special emphasis on protecting large core areas of shoreline habitat within 19 identified Biodiversity Investment Areas.

6.0 Major Stressors and the Nearshore

The previous chapter discussed the state of the nearshore ecosystem in terms of ecological and human health, the top level in Figure 2, illustrating the SOLEC '96 framework. This section deals with level 2, the stressors affecting the ecosystem and sources which appear in level 3.

The Great Lakes nearshore ecosystem evolved, in many respects, as a result of naturally occurring stress. Coastal wetlands are maintained by changing lake levels which periodically drown or dry out invading species and leave conditions where unique assemblages of wetland plants can compete. Terrestrial conditions are often severe due to changing lake associated groundwater water levels and unusual conditions such as those in beach and dune areas. Also, the oak woodlands and savannas evolved with periodic droughts and the presence of fires. The nearshore waters are not as obviously stressed, but they too are far more dynamic than the stable habitat provided by deep water areas.

In addition to the continuing natural changes, the nearshore has evolved with gradual long term changes over thousands of years. Natural changes such as the advance and retreat of glaciers or long term changes in lake levels occur slowly enough for the living components of the ecosystem to respond through geographic movement and natural selection. Human induced stressors cause change in far shorter time frames which do not allow time for adaptation or recovery.

Human activities have now added new stresses to the nearshore during a relatively brief period of time. This has been a factor in invasion and explosive growth of exotic species which benefit from human disturbance. Disturbed and simplified systems are least able to resist invasion. Very often the invading species itself results in a further simplified and less stable system, e.g. lamprey elimination of top predator fish.

Highly evolved and complex communities of organisms tend to take a long time to become established and often include species that are sensitive to disturbance to which they are not adapted. On the geologic time scale, the 10,000 years since glaciation of the Great Lakes is relatively brief. Compared to older areas of the earth this ecosystem was young and simple at the time of European settlement. The aquatic system was dominated by relatively few fish species. When they were exploited through excessive harvest and stressed by pollution and exotic species, native populations crashed and some became extinct.

Underlying many of the adverse effects on the ecosystem were changes in the processes that supported it. Two major examples are the exclusion of fire from the native landscape and changes in hydrology. Much of the vegetation of the region, particularly the prairies and oak woodlands, had evolved with fire which occurred naturally or at the hand of Native Americans who arrived soon after the glaciers departed. When fire was suppressed through fragmentation of the landscape and through active control, conditions changed so that species that had evolved with fire no longer had an advantage. As a result, native and exotic species usually suppressed by fire began to take over the landscape.

Changes in hydrology include: volume, timing and duration of stream flow; surface moisture and groundwater; and lake levels. Stream flows are strongly affected by both agricultural and urban land uses. In most cases, peak flows were minimized by native landscapes which caused much rainfall to be absorbed into the soil and runoff to be slowed by vegetation and other physical obstructions. Also, flows during drier periods tended to be maintained by continuing release of shallow groundwater. Replacement of native plants with crops and urban uses led to major acceleration in runoff. This in turn caused flood damage including major changes in stream beds, lack of water during some periods and serious loss of habitat. In some urban streams habitat has been seriously altered in another way by year around flows from septic fields and waste treatment plants which prevent drying of areas which were previously inundated only periodically.

In some respects, the arrival of European settlers changed the ecosystem as much by altering natural stressors such as fire and natural hydrologic cycles as they did by introducing new ones. However, some of the introduced changes were massive. Among the largest were the large scale removal of native vegetation, hydrological modification, pollution and introduction of exotic species.

6.1 Key Stressors

Key stressors of the nearshore ecosystem can be divided into physical, chemical and biological. As shown on Figure 2, physical stressors include sedimentation, hydrological modification, habitat loss or degradation. Chemical stressors include toxic contamination or excess nutrients. Biological stressors include exotic species, excess competition, pathogens, genetic loss and population disruption. There are many sources of these stressors as shown in the figure, but one underlays virtually all of the others to at least some degree, i.e. use of land by humans. The 1996 SOLEC background paper Impacts of Changing Land Use provides full discussion of the topic. Some important aspects are as follow.

6.1.1 Land Use

The largest human impacts in the past have been logging and clearing of land for agriculture. Agricultural use of land continues to have major impacts on the ecosystem, and changes in agricultural land uses continue to occur. Some agricultural stresses may be increasing as crop rotations are shortened and emphasis continues on cash crops. However, overall stress from agriculture is decreasing as the volume of pesticides used and their persistence is decreasing and environmentally compatible management practices are being adopted.

In contrast, sprawl continues unabated and is occurring at more than one scale. Urbanization is sprawling outward from central cities into the surrounding areas; and at a wider scale, construction of second homes and recreational development are occurring near amenity features, very often in the nearshore areas of the Great Lakes.

Urban sprawl has been the dominant form of growth and development in both the U.S. and Canada for the past 50 years, and can be expected to continue. A current example is in the Chicago area where from 1970 to 1990 the metropolitan population grew by 4%, while developed land grew by 55%. The city and 90 older inner ring suburbs lost 770,000 in population while the 165 outer ring suburbs gained a million. During that time the average miles driven annually per individual increased from approximately 7,000 to more than 11,000. Vehicles on the roads increased by more than a million in that 20 year period, and gasoline purchases increased from approximately 5.2 billion to 5.7 billion gallons annually.

The question at hand is whether ecosystem considerations can be given greater recognition, and whether development can take place in ways that preserve natural communities and process so that they can exist in as nearly self sustaining fashion as possible.

To accomplish this it must be recognized that development results in both direct impact on habitat and biodiversity through physical destruction, and indirectly by imposing many indirect stresses.

Looking at the basin as a whole, forestry accounts for about 40% of the basin, but it is concentrated in the northern areas, predominantly around Lake Superior. Throughout the nearshore zones, forests are increasingly being devoted to recreational use and development, particularly in the southern portions of the basin. Water accounts for about 33% or the basin. Agriculture covers about 24%.

The major impact on the ecosystem from agricultural land use came with the initial removal of native vegetation: hydrology changed; fire was removed from the landscape; and soil erosion escalated. Some progress is being made in controling soil erosion, but an example of continuing erosion and sedementation problems is the Illinois River where the undredged portions of the river and its hundreds of backwater lakes are being filled by sediment from eroding farmlands. Many Great Lakes harbors are in similar trouble.

About 3% of the land in the basin is classified as urban, but it contains a huge population which is located primarily in coastal areas. In Canada six metropolitan areas contain 66 percent of the basin population and in the U.S. 81% of the population is located in the eleven largest metro areas.

Within the nearshore zone of the Great Lakes land development is the most rapidly occurring change and is an increasing source of stress on the ecosystem. Quantification of the collective effect of land development is not available ,but localized effects are well documented.

One of the challenging aspects of land development is the number of local governments involved. For example, in the U.S. there are 213 counties that are partly or entirely within the basin and many times that number of municipalities and special districts. In both countries most land use is regulated primarily by local governments which set their own priorities. Providing these governments with the information they need to understand the ecosystem and how it can be protected in sustainable fashion is a substantial challenge.

An important aspect of protecting the ecosystem is anticipating and planning for sustainable growth. One aspect of this is identifying important ecological functions and resources and incorporating them into plans for open space and other land uses which they complement. This can be done using both nonregulatory incentive measures and regulatory mechanisms such as zoning.

How growth and development takes place is as important to ecosystem impacts as whether it takes place at all. The SOLEC '96 paper Changing Land Use looks at the costs of sprawl and how development can be modified to have less adverse impact.

6.1.2 Land Use Has Been Destructive to the Nearshore Ecosystem

Rapid population growth, intensive industrial and agricultural activity, and sprawling urban development have resulted in significant stress on the nearshore ecosystem. Nearshore waters continue to be polluted , and in some cases have been severely contaminated, from sanitary sewage, industrial toxic substances, and urban and agricultural runoff.

Although there has been some improvement in air pollution from industrial sources, air quality affecting living organisms in the nearshore ecosystem is of concern, especially for ground level ozone, as urban transportation systems become more energy intensive, increasing greenhouse gas releases continue to pose a challenge. Wetlands and other natural habitat areas within the nearshore ecosystem are under threat of destruction and alteration by increasing urban sprawl and second home cottages. Finally, shoreline protection and other shore hardening caused by development have interfered with natural shoreline processes and, in some cases, resulted in the irreversible loss of beaches.

6.1.3 Current Land Use is not Efficient

Notwithstanding recent attention to more intensive forms of urban development, development throughout the basin continues to be predominantly land consuming urban sprawl. High density intensive development in urban areas facilitates the economic viability of public transit as an alternative to the private automobile for commuters. Urban communities with higher population densities typically require less costly municipal infrastructure through sewers and roads, use less water and energy and create less pollution. As a result, taxation to pay for municipal services may be significantly lower, making these communities more competitive from that perspective.

Economic efficiency resulting from reduced urban sprawl is accompanied by higher environmental efficiency. Urban services, such as transportation and water and wastewater can be provided at reduced levels of energy and natural resource use. Reduced use of natural resources generally implies reduced pollution and stress on ecosystems, including the nearshore ecosystem. Urban sprawl has also contributed to the loss of some of the best farmland in the basin, as housing and industrial development replaces agriculture. Farming that shifts to lower productivity soils and at greater distances from final markets is less efficient and more resource intensive. In addition, urban sprawl promotes the clearing and conversion of natural habitats including wetlands.

6.1.4 Planning and Incentives are the Keys to Sustainability

Despite increasing levels of awareness about the consequences of urban sprawl among urban officials and planners at all levels of government, urban sprawl continues to be the major pattern of new development. The incentives of relatively low market prices for agricultural and natural lands and the ease of conversion of those lands to other uses continues to favour low density development. Planning systems that are intended to bring order to and ensure balance in development have not been able to contain urban sprawl. Fragmentation of responsibility for planning issues among levels of government has contributed to this problem. Agricultural land protection through land banking, conservation easements, or specific prohibitions against urban encroachment on agricultural and natural lands are options to this end.

Finally, market place incentives that would promote more sustainable development, such as full cost, user-pay development charges or impact fees, are inconsistently applied in different jurisdictions. At the same time, many jurisdictions believe they should compete for short term jobs and tax revenues that come from new development. Direct and indirect subsidies for new development through public provision of roads, water, sewers and sewage treatment facilities mask the real long term economic and environmental consequences of urban sprawl and continue to favour unsustainable development.

A set of indicators by which land use impacts on the nearshore ecosystem have been evaluated is outlined in Table 7 . These indicators are intended to be instructive and to generate discussion around how to measure the impacts of human land use activities on the ecosystem. It is hoped that this initial identification of indicators related to land use will assist in the determination of information research needs for better understanding the impacts of land use on the nearshore and other ecosystems.

6.2 Physical Stressors

Major physical stressors and sources are: sedimentation, habitat destruction, hydrologic and fire regimes, climate and ultraviolet radiation, lake level regulation, hydro and thermal electric power generation, extraction of minerals, shoreline modification, dredging and filling, land clearing, marine transportation, and the interruption of the transport of sediments by longshore currents.

Lake Level Fluctuations Lake level fluctuations contribute to shore erosion; sediment transport; sand dune maintenance; formation and maintenance of coastal wetlands; fluctuations in nearshore groundwater and its related effects. As discussed in the coastal wetlands paper, lake level changes are essential to the ecological health of coastal wetlands. Seasonal and long term fluctuations in levels are determined primarily by precipitation and evaporation, but are controlled by humans in Lakes Ontario and Superior, in addition to being influenced by humans in the other lakes.

At least two fish species are affected by water level and flow regulation. Lake sturgeon have declined through loss of spawning habitat and blockage of migration routes. Walleye were historically common in the St. Lawrence River, but numbers declined sharply following the construction of the St. Lawrence Seaway and Power Project in 1958, when rapids and rocky whitewater areas, preferred spawning habitat, were flooded.

Thermal-electric Power The effects of power production can be significant. About 90 thermal-electric plants draw their cooling water directly from nearshore waters and use once-through cooling . Fish are drawn into the plant with cooling water. Fish too large to pass through screens are impinged and killed; smaller fish that pass through screens (entrainment) are killed by collision with screens and other surfaces in the system, or by heat/cold shock. Estimates are that more than 100 million fish were killed by impingement and more than 1.28 billion by entrainment annually in the 1970s in the Great Lakes and connecting channels. More recent summaries, which include all power plants sited on Great Lakes and connecting channels, indicate even larger fish losses. Recent losses of young fish in Lake Michigan and western Lake Erie are significant, representing 3-10 % of the total annual production.

Disposal of coal ash from power plants is a growing problem. Leaching and aerial transport can result in deposition of coal ash into nearshore waters. Coal ash composition varies with the source of the coal; selenium and mercury are common in some ash, and radioactivity in some ash exceeds background levels in the basin.

Hydropower Production Few hydropower dams have fish ladders or other devices that allow fish clear passage over or through dams. When areas above dams were flooded, resident stream fish were replaced by species better suited to a warmer, lake-like environment. Stream fishes below dams were also adversely affected. Dams usually operate in a daily peaking mode, with exceptionally high flows occurring once or twice a day when power is most needed. As well, temperatures on the exposed stream bed fall below freezing in winter and rise above air temperature in summer, both conditions lethal for organisms living in the stream bed.

Some recent relicensing agreements for dams in the U.S. will lessen the adverse effect of dams by calling for water release patterns which will mimic the inflow pattern to reservoirs above dams. This should help set an environmentally beneficial precedent for relicensing.

Hydropower dams on the St. Marys and St Lawrence rivers are obstacles to upstream movement of fish. The Moses-Saunders Dam has a fishway designed to pass American eels, but its effectiveness is in doubt, because the number of eels recorded using it has fallen from about 1.3 million in 1983 to less than 50,000 in 1990-91. In the

Table 7. Land Use Indicators

Desired Outcomes	Indicator	Actual State	Likely Change	Data	Data* Status
Efficient Urban Development	Urban population density	Poor	Stable	Urban population per area	Good
	Suburban land conversion	Poor	Deteriorate	Land conversion rates	Mixed
	Centre town economy	Mixed	Deteriorate	Fiscal condition/ vacancies/ etc.	Mixed
	Brownfields	Poor	Stable	Number and area	Mixed
	Recreation opportunity	Mixed	Improve	Number and area of parks	Good
	Energy use	Poor	Improve	Energy usage per capita	Good
	Waste created	Poor	Improve	Residential and industrial waste	Good
	Wastewater quality	Mixed	Improve	Loadings of nutrients and toxics	Mixed
	Industrial water use	Mixed	Improve	Volume per facility/ per capita	Good
	Residential water use	Poor	Stable	Volume per household	Good
	Traffic congestion	Poor	Deteriorate	Time spent commuting	Mixed
	Transit use	Poor	Deteriorate	Public transit commuting rates	Good
Human Health Protection	Air pollution levels	Poor	Improve	Particulates and ozone levels	Mixed
	Beach closings	Inadequate data	Inadequate data	Days unswimmable	Inad. data
	Land fill capacity	Mixed	Stable	Capacity remaining	Mixed
	Stormwater quality	Poor	Stable	Loadings of nutrients and toxics	Poor
	Sewage quality	Mixed	Improve	Loadings of nutrients and toxics	Mixed

Human Health Protection Cont'd	Pollution prevention programs	Mixed	Improving	Industrial and municipal programs	Poor
	Respiratory illness	Mixed	Stable	Illness and mortality incidences	Mixed
	Fish advisories	Mixed	Improving	Allowable fish consumption	Good
	Outdoor recreation	Mixed	Improve	Opportunities and participation	Mixed
Non-Human Resource Health Protection	Wetland habitat	Mixed	Deteriorate	Number and area	Mixed
	Agriculture and natural land loss	Poor	Deteriorate	Area lost to rural development	Mixed
	Wildlife populations	Mixed	Stable	Species and population	Mixed
	Forest clearing	Mixed	Stable	Cutting rates	Mixed
	Forest replant and renewal	Mixed	Stable	Successful replant rates	Mixed
	Mineral extraction	Mixed	Stable	Depletion rates	Mixed
	Fisheries pressure	Mixed	Deteriorate	Fishing restrictions	Good
	Hunting pressure	Good	Stable	Hunting restrictions	Good
	Hardening of land surface	Poor	Deteriorate	Area of roads and buildings	Poor
	Municipal pesticide/fertilizer use	Poor	Stable	Application rates	Mixed
	Agriculture pesticide/fertilizer use	Mixed	Improve	Application rates	Good
	Conservation tillage	Mixed	Improve	Area practising no-till	Mixed
	Ground water quality	Mixed	Deteriorate	Area/number contaminated wells	Poor
	Contaminated sites	Mixed	Improve	Area and number	Poor
	Cottage and second homes	Poor	Deteriorate	Occupation per coastal area	Mixed

*Data status: Good = universally available in a usable form; Mixed = basic data available but needs assembly or variable among different jurisdictions; Poor = not available at all or severely deficient data base.

St. Marys River, the area of the St. Marys Rapids is substantially reduced because most of the flow is diverted for power production. Historically the rapids supported a productive fishery for lake whitefish; the remaining rapids now support a valuable recreational fishery for stocked trout and salmon.

Sand and Gravel Mining More than 1 million cubic metres of underwater deposits of sand and gravel were mined in 1975, the last year for published records. However, removal of gravel likely affects some species. For example, lake whitefish need gravelly substrates for spawning and fry production, and lake sturgeon require gravel and coarser rocky materials.

Marine Transportation and Recreational Boating Marine transportation and recreational boating in the basin are supported by various activities and developments that can act as stressors on nearshore waters. One of the major stressors in harbours and rivers is vessel passage effects. The passage of larger vessels that fill much of narrow channels acutely disrupt normal water level and flow conditions. In the St. Clair and Detroit rivers the density and diversity of submersed aquatic plants were found to be lower in channels used by large commercial vessels than in adjacent channels unused by these vessels. During periods of solid ice cover vessel passage can cause removal of shoreline vegetation.

In the St. Marys River, vessel passage in winter destroys ice bridges used by wolves and moose to cross from Ontario to Michigan, and closes naturally open pools in the ice field where bald eagles fish.

Shoreline Modification A common response to the threat of flooding and erosion is to construct dikes, revetments or break walls. By reducing erosion, these structures reduce the supply of sediments that naturally nourishes the shoreline and replaces eroded sediments. Hard shoreline structures also shift wave energy farther down shore and may locally accelerate erosion of beaches and wetlands elsewhere.

When dikes, revetments or break walls are constructed along the gently sloping shore of a wetland, a "backstopping" effect can result. Wave energy can scour sediments from in front of the revetment, leaving an abrupt boundary between upland and deep water, and eliminating the ability of a marsh to shift shoreward during high water levels.

Drainage Wetlands are drained to convert them to agricultural, urban or industrial land uses. Drainage destroys the wetland and all its natural functions. Even drains that just pass through wetlands can affect water and contamination levels with resulting reductions in diversity and value.

Dredging and Disposal of Dredged Material The major dredging related concerns are for contaminated sediments and the precautions needed to excavate and dispose of them safely without adverse impact on water quality or biota. Material dredged from all five lakes up to 1972 totalled 357.2 million m^3, and between 1985 and 1989, more than 15.8 million m^3 of sediment were dredged from the Great Lakes, about 87% of the total from Lake Erie. Most dredging projects were either small (<25,000 m^3) or very large (>100,000 m^3).

Filling destroys wetlands, eliminating all their functions. For example, 83% of the original 3900 hectares of western Lake Ontario marshland from Niagara River to Oshawa had been lost, generally to urbanization. Some sections have lost 100% of coastal wetlands through filling.

Diked Wetlands Dikes are built to surround intensively managed wetlands. However, isolation from lake waters and the surrounding landscape results in elimination or reduction of many of the functional values of wetlands. These include flood conveyance, flood storage, sediment control, improvement of water quality, and habitat for fish, shorebirds and many less common plants and animals. Diking is more common in the flat flood plains of the Lower Lakes basin , where about 17% of Canadian coastal wetlands and 51% of US coastal wetlands have been diked .

Road Construction Many of the coastal wetlands on all the lakes are crossed by roadways. The hydrology of these wetlands is altered by constriction under narrow bridges placed along causeways that partially dam the river and wetland. Excessive sediments are deposited allowing invasion of plant species that would otherwise not tolerate the hydrologic regime of the original wetland. Water-level changes due to seiches are also dampened by the reduced connection with the lake. In addition, roadways can contaminate wetlands with by-products of combustion and with road salt in winter.

Climate Change - A potential stressor Vast changes have occurred in the past due to climatic change and the evolution and radiation of new species. However, those changes occurred over thousands and tens of thousands of years. The slow speed of those changes allowed the ecosystem to adapt and adjust to them. While some species became extinct, many more moved geographically or adapted sufficiently to survive, preserving biodiversity. At today's rates of change, the system is losing resiliency. Exotic species are surging into the ecosystem, enjoying temporary advantage due to the absence of predators and pathogens. However, they are driving out species and stocks which are adapted to the full range of conditions which occur over hundreds and thousands of years in this ecosystem. To the extent this "genetic memory" is lost, the system loses diversity and resiliency. When the exotic species crash, or just become limited by adaptations within the system, the naturally evolved genetic diversity that would ordinarily fill the niches may be gone.

Mathematical models suggest an average warming of 3-8°C for the Great Lakes basin by the later half of the next century. The greatest impacts are expected to be the indirect changes in other climate conditions, not just temperature change. Rainfall patterns, soil moisture, evapotranspiration, snow season length, extreme heat events and the frequency and severity of weather disasters such as thunderstorms, hail and tornadoes are all expected to change regionally.

The most profound direct impact of changes in climate is on the hydrological cycle of the Great Lakes and future water supplies. This could result in:

- Net basin supplies declining significantly (by 2 to 113 %) while long term lake levels could fall to or below historic lows, and mean outflows would be reduced;

- Outflow to the freshwater portion of the St. Lawrence River Basin declining 20 to 40 % with salt water intrusion potentially reaching further upstream;

- Ground water recharge rates declining. Water temperatures warm and buoyancy driven turnover or mixing of the water in lakes might occur less frequently;

- Depletion of dissolved oxygen; changes in water quality; with fish and other aquatic organisms being affected.

- Loss of native plants and animals as exotic species invade;

- Impacts on the forestry industry including species shifts north, and increased risk of fire, insects and drought;

- Agricultural production will also be impacted as the frequency and severity of drought is expected to increase as evaporation increases with rising temperatures;

- The sport and commercial fishery will be affected as warm water species become dominant, and habitats change for native species;

Other aspects of society that could be affected include tourism, transportation, and power generation.

Ultraviolet-B Radiation With the thinning of the protective ozone layer (especially at both poles) more ultraviolet (UV) radiation is able to penetrate the through the earth's atmosphere. This has implications to biological ecosystems (in the form of increased stress on living tissue) and their ability to adapt (especially to UV-B).

Vulnerability of freshwater ecosystems to UV-B is dependent on how deep the UV radiation penetrates. This in turn depends on the clarity or amount of suspended sediments in the water. Increased clarity can mean increased penetration of UV-B radiation. The biological health of the resident biota; the time that the biota spend in the near-surface region; and the stability of the near-surface region are other factors to consider regarding UV-B effects. An early effect is expected to be a reduction in algal productivity.

Other effects include frog populations that are dwindling across many regions of mid-latitude. Since frogs are an integral link in northern and mid-to-high latitude food chains, declining frog populations place migratory birds and higher order predators at risk.

6.3 Biological Stressors

Biological stressors of nearshore ecosystems include native and exotic organisms including plants, animals, insects and diseases. The clearest examples of biological stressors are exotic species which are discussed separately in the next section. Native species can also become stressors when populations get out of balance. An example of this is removal of key predators in either aquatic or terrestrial systems. The resulting over population of prey species such as deer or forage fish can have severe impacts on other components of the ecosystem. Another example is excess predation due to excessive predator to prey relationships. Closely related to this is excessive human harvest which depletes the productive capacity of the living resource. The cause of population disruptions can be either natural or the result of human activity, but human caused impacts tend to be longer lasting.

An example of natural causes would be weather events which cause food shortages or other stresses and population changes.

Over fishing Separating the effects of overfishing from those of habitat degradation and the introduction of exotic species is difficult or impossible in many cases because all three factors were operating simultaneously. However, the effect of overfishing on the walleye in Lake Erie is clear. Commercial catches declined from 2.3-2.8 million kg in the late 1950s to about 25,000 kg in 1971. With more stringent catch regulations now in place for both commercial and recreational fisheries, walleye now support a self-sustaining fishery shared by both recreational and commercial interests.

Exploitation of fish stocks in the other lakes resulted in the decline of the native fish community throughout the system and allowed introduced species such as alewife and smelt, only marginally suited to the Great Lakes, to establish rapidly and to accelerate the decline of the native fish community.

Overfishing has also contributed to ~~the~~ a loss in the genetic diversity of the native fish fauna of the Great Lakes. This includes the loss associated with the extinction of several native species, including the blue pike and some deepwater ciscoes (whitefishes), and to the loss of genetic diversity resulting from the extirpation of local stocks of native fishes by overfishing, together with habitat loss and the introduction of exotic species. Although the loss due to species extinctions is relatively obvious and unequivocal, the loss due to the extirpation of local stocks is less so.

Waterfowl that nested in the Great Lakes region, or migrated through it and used the nearshore waters for feeding and resting areas, were sharply reduced by market hunting and habitat destruction.

Exotic Species Global transfer of exotic organisms is one of the most pervasive and perhaps least recognized effect of humans on aquatic ecosystems of the world. Such transfers to new environments lead to loss of species diversity and extensive alteration of the native, or pre-invasion community. These changes, in turn, have broad economic and social effects on the human communities that rely on the system for food, as a water supply, or for recreation.

The rate of introduction of exotic species has increased markedly since the 1800s, as human activity in the Great Lakes basin increased. Almost one-third of the introductions were reported in the past 30 years. The first introductions of aquatic plants occurred when ships discharged solid ballast in the late 1800s. The opening of the St. Lawrence Seaway in 1959 greatly increased the number of ocean-going vessels entering the Great Lakes and dramatically increased the entry of exotic species by ships. Deliberate releases declined after the 1800s, entry by canal increased slightly through 1959, entry by railroad and highway occurred mostly in the 1800s, and unintentional releases were consistently high since the late 1800s.

Of the fish pathogens introduced into the Great Lakes, *Glugea*, a protozoan, caused extensive mortality in rainbow smelt in Lakes Erie and Ontario in the 1960s and 1970s. A second pathogen, the cause of bacterial kidney disease, has been implicated in the massive mortalities of Pacific salmon in Lake Michigan in 1988-1994. Other introduced pathogens cause salmon whirling disease and furunculosis, mainly in fish hatcheries, where fish are more vulnerable to outbreaks of disease.

The arrival of the zebra mussel in Lake St. Clair in 1986 set the stage for long term changes in the structure of pelagic and benthic communities in the Great Lakes and in the economic and social future of lake users. The zebra mussel which feeds by filtering particles from the water, may cause substantial changes in the food web by removing most phytoplankton and smaller zooplankton and other suspended materials from the water and depositing them on the bottom. This action greatly reduces the plankton community and the amount of food available to planktivorous fish that feed above the bottom, and greatly increases the food supply for benthic communities and bottom-feeding fish. As a result, the overall production of fish in the Great Lakes will probably be reduced.

Introduced plant species outnumber all other groups of introduced organisms, but the effect of only a few of these is known. Purple loosestrife has spread throughout the Great Lakes basin, replacing cattail and other native wetland plants and making wetlands less suitable as wildlife habitat. Eurasian water milfoil is also increasing its range in the Lake St. Clair ecosystem. Massive beds of the plant can make boating and swimming impossible and reduce fish and invertebrate populations.

In summary, the collective ecological, social, and economic effects of exotic species in the Great Lakes are enormous. Most introduced species have not been thoroughly studied to determine their effects on the ecosystem, but some clearly have had serious adverse effects. Introduced species exist at almost every level in the food web and their effects must certainly pervade the entire Great lakes aquatic community. As long as human-mediated transfer mechanisms persist, and habitat alterations and other factors that stress native aquatic communities are allowed to occur, the Great Lakes ecosystem will be at substantial risk from exotic species.

6.4 Chemical Stressors

Chemicals play important positive roles in ecosystem health when present within normal ranges. Toxic chemicals, however, can have adverse effects on animal and plant populations.

In heavily populated areas the salt used to de-ice roads in the winter may change the chemical balance of nearshore terrestrial as well as aquatic ecosystems. It is estimated nearshore waters are three times as salty as in the mid-1800s. The impacts to terrestrial ecosystems is unknown although it is thought that salt from road runoff is a factor in the spread of some exotic species such as the common reed (*Phragmites communis*).

A change in the acid-base balance of systems may affect plants and surface water. At this time, the effects of acid-base balance changes on nearshore terrestrial ecosystems are not known.

Most chemicals are essential to life and have been present in the system for a very long time. The exception to this are synthetic substances. Human activity has both changed the concentrations of chemicals in the system and added substances which are entirely new to the system. Synthetic substances such as chlorinated organic pesticides did not occur naturally and their effects are not completely known. What is clear is that persistent toxic substances have had adverse effects as discussed in the 1994 SOLEC paper on toxic contaminants and in the 1996 nearshore waters paper.

6.4.1 Pollution

Discharges and Spills Pollution has severely degraded portions of the Great Lakes system. Aerial inputs of some contaminants are also significant. Organochlorine compounds have reached unacceptably high levels in Lakes Michigan and Ontario; these and other industrial pollutants, including oils and metals, are at high levels in sediments in some areas in the connecting channels and in certain harbors throughout the system.

Agricultural Runoff Annual loadings of suspended solids and sediments to the Great Lakes total 60 million metric tons, about 80% of which comes from erosion of Great Lakes shorelines and the rest from tributary inputs. Total loadings vary from about 2.8 million metric tons in Lake Huron to about 22.5 million metric tons in Lake Michigan. Nutrients and contaminants are associated with this sediment.

Persistent Toxic Contaminants in Water, Sediment, and Biota A variety of organochlorine contaminants and metals bioaccumulate in fish. Contaminants often undetectable in water samples may be detected in small, young-of-the-year fish. Because fish integrate spatial and temporal changes in contaminant availability, contaminant body-burdens provide a good basis for assessing environmental change. Forage fish also provide an important link in assessing contaminant transfer to higher trophic levels (eg. fish eating birds, mammals). A common forage fish, the spottail shiner (*Notropis hudsonius*) was selected as the principal biomonitor. This fish remains close to shore all of its life, and is a good indication of nearshore contaminant concentrations. An example of the trends in contaminants in this nearshore fish species is shown in Figure 5. For a fuller discussion of toxic chemical trends in the Lakes, please refer to the SOLEC '94 paper Toxic Contaminants and the SOLEC '96 paper on Nearshore Waters.

Airborne Contaminants The atmosphere has been shown to be an important and sometimes predominant pathway for toxic contaminants to the Great Lakes. There have been several studies dealing with the atmospheric loadings of contaminants and their relative importance as compared to point sources, tributary loadings etc. Recent publications concluded that gas flux (transfer) is the most important process for several of the priority pollutants (pesticides, PAHs, PCBs), and as significant as dry and wet deposition for others (heavy metals). Unfortunately gas transfer is not well quantified, and integrated air-water assessments for each lake are needed. To establish the relative importance of the atmospheric contribution to the loadings of contaminants to the Great Lakes, it is essential to have better loadings data from point and non-point sources.

6.4.2 Nutrient Enrichment

The control of excess nutrients and related problems in the open waters of the Great Lakes is a major success and is reported in the 1994 SOLEC paper Nutrients: Trends and System Response and elsewhere. However, problems caused by excess nutrients remain in some embayments and other localized areas.

In wetlands the nutrient content of the water is important in determining productivity and species composition. Rare plants may disappear and other plants adapted to low nutrient environments can be killed by excess nutrients. In addition, nutrient enrichment may cause excessive algal blooms. Depletion of dissolved oxygen may occur when these plants die and decay. The low diversity of fish and wildlife together with the slimy, foul-smelling water in turn discourages recreation.

Both urban and rural areas contribute human-induced nutrient additions to streams leading to coastal marshes. However, with modern sewage treatment reducing nutrient loads, agricultural practices are now the biggest source.

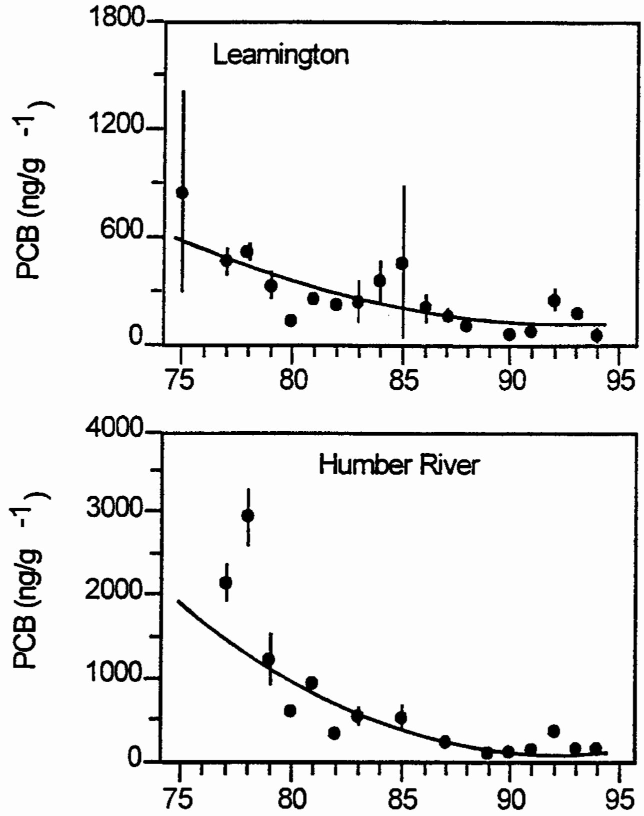


Figure 5. Contaminant concentrations in the spottail shiner

7.0 State of Information and Knowledge of the Nearshore

A primary source of information for an assessment of the state of information management was gathered from a questionnaire sent to over 1000 Canadian and U.S. federal, provincial, state, regional, non-government agencies and academia. The survey results attempted to identify existing data and information for the nearshore zone of the Great Lakes. The survey results do not, however, give an indication of the value of these databases for assessing the state of the nearshore ecosystem. In particular, they do not address what information is needed, and not available.

Data have been collected and analyzed in the Great Lakes for many years, for a variety of studies. A very extensive data base exists on the physical, chemical and biological components of the Great Lakes Basin ecosystem. There are two critical issues to consider in data and information management: 1) How to ensure access to data collected, and 2) What information is (required to be collected) needed in the future.

SOLEC '96 authors have proposed a set of indicators in an attempt to identify what needs to be collected, and why. In the background paper dealing with information management we have assessed the state of information to measure these indicators, and the reader is referred to that paper for details.

7.1 Information Indicators

Four indicators have been used to assess the overall state of data for all the indicators used in this paper: data coverage; data time frame; data applicability; and data usability.

Data coverage refers to how well the data cover the Great Lakes nearshore area. If sufficient data are available for the entire Great Lakes shoreline, then the rating is "good". If data only cover a small portion of the Great Lakes shoreline, then the rating is "poor"

Data time frame refers to how recent the data are. Ongoing monitoring programs that collect data on a regular basis are considered good" while data that have been fairly recently collected, but need updating are considered "fair", and old data are considered "poor".

Data applicability refers to how well data can be used to address the indicators discussed in this paper. If data are available and applicable to one or more indicators than this is considered "good", and if the data do not address any of the indicators identified then they are considered "poor.

Data usability, refers to how well the data can be used across disciplines. If data can be used for more than one purpose, having cross-discipline applications then they are rated "good" . If the data are discipline specific then they are considered "fair". If the data are collected for one unique study and have no use beyond that one study then they are rated "poor".

An evaluation of the overall state of data based on these four categories is presented in Table 8.

7.2 General Findings

Since there are no widely accepted indicators for measuring the state of the nearshore, data have generally been collected on an as need basis by individual agencies, and their utility in assessing the state of the nearshore is questionable in any particular situation.

Binational activities carried out under the Great Lakes Water Quality Agreement (Lakewide Management Plans, Great Lakes International Surveillance Plan) have provided major data coverage. Unless the data collection efforts are repeated however, the data quickly become out of date. On-going monitoring programs provide the best long-term data that can be compared over the years. However, a number of these programs seem to have been ended in recent years.

Table 8. Overall State of Data

Desired Outcome	Indicator	Rating	Basis for Rating
Data to measure all indicators	Data coverage	Fair	Only a few data sets cover the entire Great Lakes shoreline. Most are lake or site specific. Data collected on behalf of international studies (e.g. surveillance or Lakewide Management Plan studies) generally have the best data coverage.
	Data time frame	Fair	Some long term monitoring programs have excellent up to date data such as the water level information. Large data sets collected on a one time basis (e.g. shoreline classification) are becoming out of date.
	Data applicability	Fair	Most data sets have some applicability to the indicators described above. If they cannot be used directly, they can be used in support of measuring the indicator.
	Data usability	Fair	Some data are useable for a wide range of applications, while others are very study specific.

7.3 Nearshore Information Management

For data and information gathered for the nearshore of the Great Lakes to be of value, they need to be readily accessible, reliable, and shared effectively among partners. Information management of all the data gathered for the nearshore is not a simple issue. Many agencies collect, analyze and store information pertaining to the Great Lakes. Today's electronic technology should facilitate identification and access of data sources and assembly of information.

There are a number of issues which have an influence on nearshore information management. These issues are even more pronounced when dealing with an area as large as the Great Lakes and considering the large number of agencies, organizations, institutions, and levels of governments involved. The issues are:

I. Data Collection, which includes:

- homogeneity or uniformity of data;
- compatibility of data among disciplines;
- compatibility of data among agencies; and
- standards, guidelines and units to ensure compatibility and homogeneity.

ii. Documentation/cataloguing of Data (Metadata)

The amount of data generated and stored presents serious challenges to users of data. Large quantities of data become unmanageable if the user has no way of knowing what the data are, where to find them, or how to use them.

iii. Medium of Storage/archiving

If data are not stored properly, the data will be lost. There are no set guidelines for data storage, back-up or maintenance amongst most of the agencies compiling nearshore data.

iv. Availability and Access of data including:

- format constraints;
- ownership/propriety/right-to-use; and
- commercialization/revenue questions.

v. Data Integration

Integrating data sets becomes important when one is involved in a multi-disciplinary activity such as SOLEC, or lakewide management planning. Problems arise when data sets are combined. When two spatial data sets are overlaid, for example, the accuracy of the resulting information is less than the least accurate input data. Integration is key to meaningful policy formulation and planning decisions, yet to be useful in multiple applications, data must be collected and automated to specified and agreed to standards, including geographic coordinates to allow for this integration of data.

vi. Securing and Protecting Data

The provision of information should not be done without proper assurance that the data will not be used improperly. When collecting data from humans, for example, confidentiality is a critical issue. Storage and common access to data on humans requires additional controls. It is important therefore, that proper care be taken in securing and protecting data and information, including proper documentation of the data to minimize the data being used for purposes other than that for which they were collected.

vii. Data Stewardship

Storage and maintenance implies responsibility for the data and requires the appropriate resources and agency commitment. The question of who maintains the database is of particular importance when more than one agency has been involved in the development of the data, and requires access to the data.

viii. Methods for Dissemination

Until very recently, data and information have generally been disseminated by tape, or disk and sent by mail to the user. Within the past 5 years CD ROMs have been used more often for data dissemination. Even more recently the use of the Internet using file transfer protocol (ftp) for data transfer has become more common. This is by far the fastest method of data transfer and dissemination. However not all agencies have this capability, and even amongst those that do, not all individuals are aware of this method of data transfer, plus clogging the Internet with huge data transfers violates one of the informal rules of Internet etiquette.

8.0 Management Challenges

8.1 Overall Challenges

Managers, scientists and the public face a myriad of challenges in dealing with the Great Lakes nearshore ecosystem. Four overall challenges have been identified as described below. They are followed by more detailed challenges identified by the authors of the background papers for their subject areas.

The fundamental challenge of the nearshore is for managers and decision makers to be able to understand it as an ecosystem and obtain enough information to make informed decisions. Obtaining and communicating such information is a formidable challenge for researchers and those responsible for monitoring the state of the ecosystem.

The SOLEC framework of ecological health - stressors - sources offers a way to organize thinking about the system and provides a framework for developing indicators to be used at all three levels to define desired states and to measure progress.

Although the ecosystem is endlessly complex, there is an urgent need to agree upon desired states, the present state, and key steps needed to attain what is desired. Without this it is difficult to provide rational decision making or to measure progress.

The development of community based Remedial Action Plans for Areas of Concern, Lakewide Management Plans, Fisheries Management Plans and various species recovery plans provide an opportunity to involve the necessary interest groups and develop practical plans. But they have yet to reach that potential.

Specific challenges that need to be met in the next two years include:

- Bringing together available information on the state of the nearshore ecosystem into accessible GIS based formats and systems. This is particularly the case for living resources such as: plant and other biological communities; various kinds of coastal wetlands including information on quality and which areas are threatened with loss; and fisheries including fish stocks and critical habitat.

- Developing easily understood indicators to support understanding of the state of the system and obtaining wide spread agreement on what needs to be done; and to measure progress.

- Integrating the concepts of biodiversity and habitat into existing programs traditionally devoted to pollution control or natural resource management for harvest.

- Integrating LAMPs, RAPs, and fisheries management plans so that they become fully viable management mechanisms, useful for decision makers throughout the Great Lakes Basin Ecosystem in taking action and assessing results.

8.2 Subject Area Challenges

8.2.1 Nearshore Waters

Management actions are required to protect wildlife in the nearshore. In particular:

Controls may be needed now or in the near future to protect double crested cormorants, black-crowned night herons, ring-billed gulls, common terns, great egrets, black and Foster's terns, little gulls, and Caspian terns. These controls consist of colony protection, control of competing species, and habitat protection and rehabilitation.

With respect to waterfowl, protection is required for roosting sites of Dabblers and Geese, except the domesticated Canada Goose, which needs population control, and protected areas are needed for Divers - Bay Ducks.

Aquatic raptors such as eagles and osprey need particular attention, including nesting platforms for Osprey and the erection of platforms in specific areas for specific pairs, restrictions on contaminants, restricted access to all nest sites, especially new ones.

To protect fisheries, a coal ash storage/disposal policy is needed for power plants sited in the coastal zone or on basin tributaries, to protect nearshore waters from ash and leachate.

A Water Management Plan to accommodate the needs of the fish community and those of power producers should be developed for Great Lakes tributaries and interconnecting channels used for electro-generation.

Open lake disposal of uncontaminated materials needs to be addressed in terms of spawning grounds and potential interruption of spawning migrations. Research is needed to assess the effects of dredging activities on these species so that adverse effects can be avoided or minimized.

Monitoring-based estimates of loading rates of pesticides into the Great Lakes are virtually absent from the published literature. Knowledge of these loads in the Great lakes is needed to (1) develop and refine lake-wide management plans (LaMPs), (2) predict equilibrium concentrations of herbicides in the Great Lakes and interpret their effect on human and ecosystem health, and (3) provide a basis for assessing the status of agricultural pollution on regional and national scales.

The full and productive use of the diverse array of habitats in the Great Lakes nearshore waters requires that the genetic diversity of the remaining native species be protected by actions taken to perpetuate all recognized stocks of each species.

Joint Canadian-U.S. studies of benthic fishes in a gradient of polluted to pristine locations, using standard methods, would enhance our knowledge of the development of tumors and their usefulness as indicators of polution.

Evaluation of the dynamics of waterfowl use of zebra mussels should be monitored.

Goldeneye and common merganser are often attracted to nearshore waters kept ice-free by heated water discharges or mechanical means. Each new ice-free area caused by human activity needs evaluation.

To maintain genetic diversity, protection is needed for traditional colonial waterbird nesting sites that have large and varied populations, especially in the lower lakes where there is high demand for developmental lands.

Protected sites for unique feeding opportunities for waterfowl during migration are critical.

For aquatic raptors, maintenance and creation of nesting sites (super-canopy trees and artificial platforms) and accessible open water in winter in nearshore situations are essential.

To maintain low phosphorus loadings and to avoid reversing hard won progress, sewage treatment will have to become more stringent as populations increase. Human sewage effluent in the lakes will be a management issue for the foreseeable future. Optimization of existing infrastructure and application of necessary technologies are needed if a reverse trend to worsening conditions is to be avoided.

The problem of untreated sewage discharges by combined sewer overflows must be addressed.

Impacts from nearshore aquaculture operations needs to be assesed and management action taken to prevent nutrient enrichment, and the possible spread of disease from these operations.

8.2.2 Coastal Wetlands

There is a need for a commonly accepted system of classification for wetlands, and a need for more systematic information on the quality, quantity and rate of loss of wetlands.

Development of indicators of wetland health is needed, to track the state of wetlands, and aslo as an educational tool.

8.2.3 Land by the Lakes

Future stewardship of lakeshore lands needs to be oriented towards the goal of protecting and restoring ecosystem health, as part of broad international efforts to restore health to the Great Lakes ecosystem as a whole.

This stewardship effort should have two components:

- A concerted international effort to complete a core set of protected areas along the Great Lakes coast, based both on representative examples of enduring features of the full range of coastal landscapes and on protection of special lakeshore biodiversity elements and communities; and,
- Development of coordinated shoreline management measures in areas between the core protected areas to ensure that ecological processes are sustained, and that shoreline areas with human uses also contribute to biodiversity conservation.

8.2.4 Plan for Protection and Recovery

The 19 Biodiversity Investment Areas are clusters of shoreline areas with exceptional biodiversity values which present key opportunities to create large protected areas. These areas will preserve ecological integrity, and ultimately, help protect the health of the Great Lakes themselves.

8.2.5 Involve Private Landowners

Protecting ecosystems and their processes and functions only within fence lines is not sustainable, nor does it contribute fully to the quality of life for humans and other organisms. One alternative is to negotiate management agreements, possibly through conservation easements that protect ecosystems. Many easements are perpetual, that is, are transferred along with property ownership (The Nature Conservancy, 1992).

8.2.6 Educate to Build Support

Education for all citizens about shoreline ecosystems and their important functions is needed. A translation of information into a common language will help the dissemination of important facts. Whether in the classroom with school-age children or with individual citizens, information is key to making wise decisions about ecosystems.

Need to identify means other than acquisition by public agencies to protect high quality areas.

Knowledge and information gaps are hampering conservation efforts in several areas. We need to determine:

- the effects of human-induced water level changes on the functioning of shoreline natural ecosystems;
- long-term effects of artificially-high levels of beach/dune erosion or nourishment on adjacent natural ecosystems;
- the impacts and responses of the 12 special lakeshore community types to the stressors identified in the report, both individually and synergistically; and,
- the representation of coastal biodiversity within ecoregions and ecodistricts, to assist in identifying candidate areas for protection or restoration.

8.2.7 Land Use

Making environmental protection a priority objective for urban development is critical.

Prohibitions against sprawl—where it is already creating environmental and social problems— would provide much needed breathing space and send clear messages to the development industry and the residential and commercial markets that it serves. Strong protection against farmland conversion, through agricultural land banking and the greater use of conservation easements, has not been embraced on either side of the Great Lakes.

Removal of hidden financial and economic biases in favour of sprawl and against inner city redevelopment and more compact urban development, as well as the adoption of a full cost-pricing approach for different types of development, is especially important.

There is need for public education! The environmental and social impacts of suburban lifestyle are, obviously, not well understood and appreciated by the public. Education of the public by state and provincial agencies could help to reduce the demand for sprawl housing—for example, by undertaking a public education campaign to advertise the environmental, social, and long-term economic costs associated with sprawl.

If it is the economics of cheap agricultural land and subsidized municipal services that have made sprawl so popular, it will take economic disincentives to discourage even greater sprawl. Development charges and impact fees are perhaps the most powerful tool for bringing the real cost of sprawl into the market for homes and new industrial and commercial locations. That these fees are not applied evenly and universally across the basin is a factor that continues to favour sprawl.

8.2.8 Information Management

Adopt a set of common indicators and protocols for assessing the state of the Great Lakes Nearshore ecosystems.

Develop some general guidelines and standards for collecting data on these indicators.

Identify target areas for data collection to minimize overlap and optimize the use of limited funds.

Look for partnership opportunities for data collection and identify custodians for the long-term maintenance of that data.

Agree to document nearshore data and information using some form of metadata standard.

Agree on a set of common data exchange formats.

Post metadata, and where possible, data, on the World-Wide Web.

Set up a consortium of nearshore partners over the World-Wide Web through some established Web site such as the Great Lakes Information Network (GLIN) and the Great Lakes Information Management Resource (GLIMR).

Appendix A. STEERING COMMITTEE
State of the Lakes Ecosystem Conference 1996

Conference Co-chairs:

Harvey Shear, Environment Canada
Paul Horvatin, United States Environmental Protection Agency

Canadian Members:

Doug Dodge, Ontario Ministry of Natural Resources
Fred Fleischer, Ministry of Environment and Energy
Eileen Foley, Environment Canada
Susan Nameth, Environment Canada
Dieter Riedel, Health Canada
Simone Rose, Environment Canada
Larry Schut, Ontario Ministry of Agriculture, Foods & Rural Affairs
Nancy Stadler-Salt, Environment Canada

U.S. Members:

Dieter Busch, United States Fish and Wildlife Service
Allegra Cangelosi, Northeast-Midwest Institute
Bill Cibulas, Association of Toxic Substances & Disease Registry
Susan Crispin, The Nature Conservancy
Don DeBlasio, United States Environmental Protection Agency
Michael Donahue, Great Lakes Commission
Kent Fuller, United States Environmental Protection Agency
John Gannon, National Biologic Service
Rich Greenwood, U.S. Fish and Wildlife Service/Environmental Protection Agency
Duane Heaton, United States Environmental Protection Agency
Bob Krska, United States Fish and Wildlife Service
Tracy Mehan, Michigan Department of Natural Resources
Gerry Mikol, New York Department of Environmental Conservation
Phil Pope, Purdue University
Steve Thorp, Great Lakes Commission

Binational Members:

Marg Dochoda, Great Lakes Fisheries Commission
John Hartig, International Joint Commission
Dale Phenicie, Council of Great Lakes Industries

Appendix B. To be read with Section 1.4.4

Results of the Agency for Toxic Substances and Disease Registry (ATSDR) Great Lakes Human Health Effects Research Program have shown an association between the consumption of contaminated Great Lakes fish and body burdens of persistent toxic substances. The body burdens of consumers are two- to four-fold higher than those in the general population. Other findings indicate:

- Susceptible populations, i.e., Native Americans, sport anglers, the elderly, pregnant women, fetuses and nursing infants of mothers who consumed contaminated Great Lakes fish, continue to be exposed to persistent toxic substances (PTSs) including polychlorinated biphenyls (PCBs), dioxins, chlorinated pesticides, and mercury;

- Fish consumption appears to be the major pathway of exposure to PTSs;

- A significant trend of increasing body burden is associated with increased fish consumption;

- Sport fish eaters consumed 2-3 times more fish than the general population;

- Levels of contaminants in Great Lakes fish are above the advisory limits set by the state and federal government;

- Individuals who consumed Great Lakes sport fish for more than 15 years have 2-4 times more pollutants in their blood serum than non-fish eaters;

- Men consumed more fish than women; and

- Women consume Great Lakes fish during most of their reproductive years.