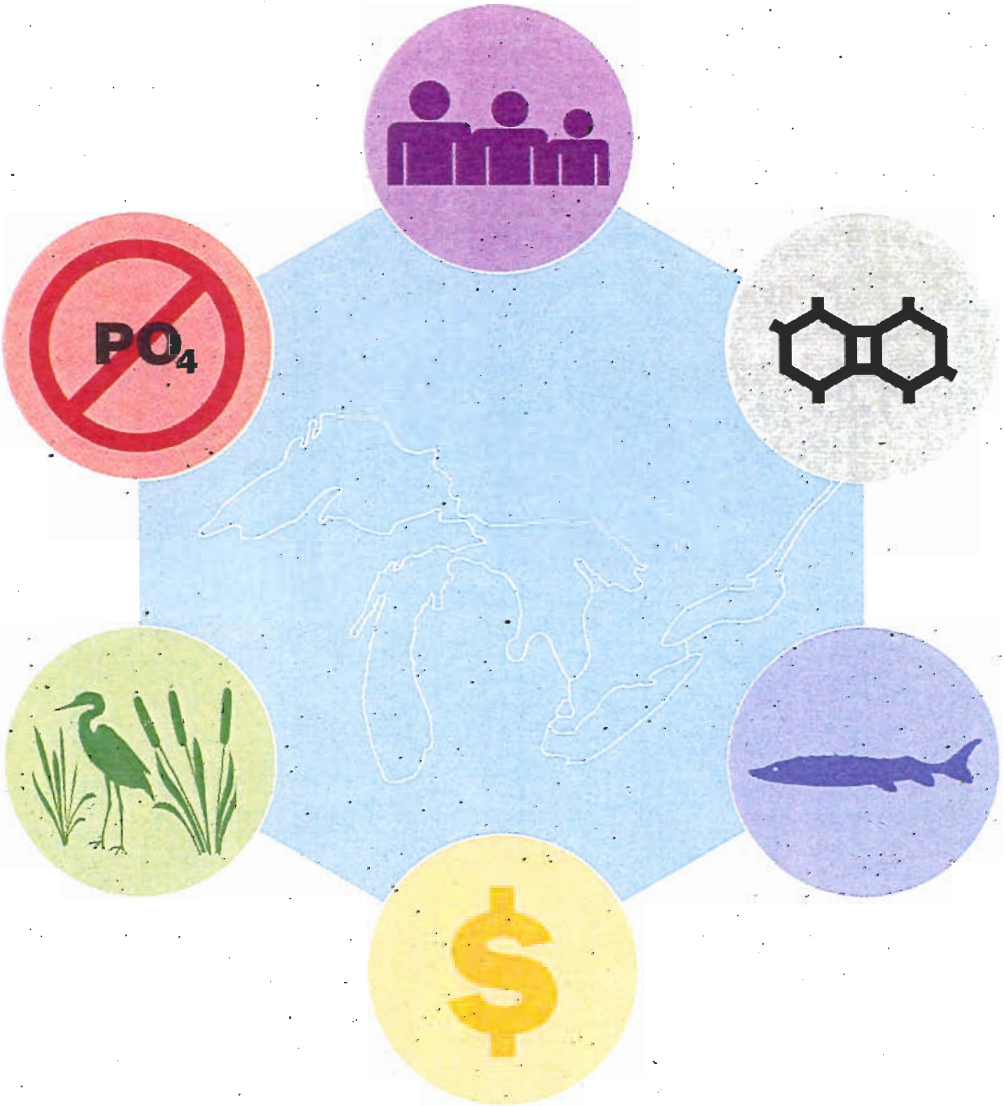
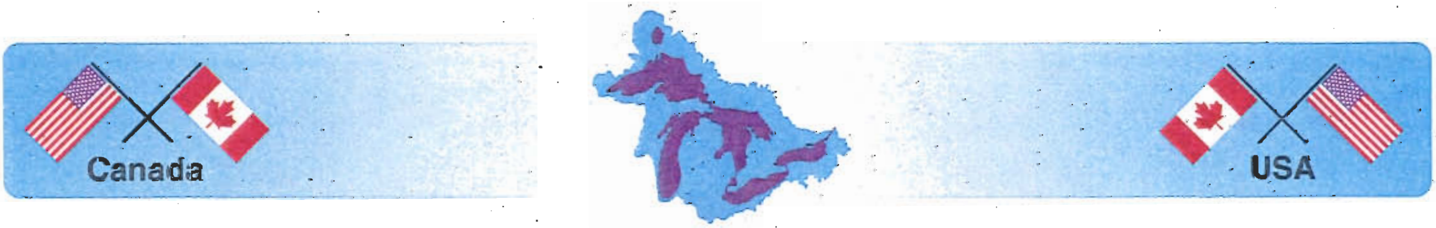
STATE OF THE LAKES ECOSYSTEM CONFERENCE

INTEGRATION PAPER

DRAFT FOR DISCUSSION PURPOSES
SEPTEMBER 1994





COOPERATING TO IMPLEMENT THE GREAT LAKES WATER QUALITY AGREEMENT
MISE EN OEUVRE DE L'ACCORD SUR LA QUALITÉ DE L'EAU DES GRANDS LACS

STATE OF THE LAKES ECOSYSTEM CONFERENCE

INTEGRATION PAPER

Prepared for

SOLEC STEERING COMMITTEE

Paul Horvatin, Co-Chair
United States Environmental Protection Agency

Harvey Shear, Co-Chair
Environment Canada

Grace Wever, Council of Great Lakes Industries
Danny Epstein, Environment Canada
Maureen Evans, Environment Canada
Jennifer Wittig, Environment Canada
Dieter Riedel, Health Canada
Mary Hegan, Health Canada
Neil Tremblay, Health Canada
Tim Eder, National Wildlife Federation
Fred Fleischer, Ontario Ministry of Environment & Energy
Kent Fuller, U.S. Environmental Protection Agency
Philip Hoffman, U.S. Environmental Protection Agency
Bob Beltran, U.S. Environmental Protection Agency
Charlie Wooley, U.S. Fish & Wildlife Service

by
Joanna Kidd, LURA Group
Toronto

For additional copies please contact:

ENVIRONMENT CANADA

867 Lakeshore Road
Burlington, Ontario
L7R 4A6

ENVIRONNEMENT CANADA

867, rue Lakeshore
Burlington, Ontario
L7R 4A6

ENVIRONMENTAL PROTECTION AGENCY

Great Lakes National Program Office
77 West Jackson Blvd.
Chicago, Illinois 60604
U.S.A.

EPA 905-D-94-002 Integration Paper - October, 1994

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

EXECUTIVE SUMMARY

The central purpose of the United States/Canada Great Lakes Water Quality Agreement is the restoration and maintenance of the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem. In support of this purpose the governments are sponsoring a State of the Lakes Ecosystem Conference (SOLEC) to review and make available information on the state of the system. A major purpose of the conference is to support better decision-making through improved availability of information on the condition of the living components of the system and the stresses which affect them. This paper undertakes to integrate the main themes of six working papers prepared as background for the conference.

The Great Lakes Basin comprises one of North America's major industrial and agricultural regions. It is an area that is rich in natural resources, linked by a strong transportation system, and host to a vibrant and growing tourism and travel sector. But the economic gains of the Basin have not been without environmental cost. The biophysical ecosystem in the Basin has been and continues to be subjected to a host of stresses — resource extraction, urbanization, deforestation, industrial practices, nutrient loading, introductions of exotic species, alterations and destruction of natural areas, the contamination of air, water and soil and others. Further historic perspective is provided in Appendix A.

The condition of the living components of the system, including humans, is the ultimate indicator of its health, reflecting the total effect of stresses on the system. The effects upon the living system, often expressed as use impairments, are also the most meaningful indicators as far as the public is concerned, i.e. can we swim, fish and drink the water? Although effects on the living system are the ultimate indicators, measures of the physical, chemical and biological stresses that affect the system are equally important in describing the state of the Lakes and providing vital information for programs that restore and protect the integrity of the ecosystem.

Indicators are used to measure the state of living components in terms of both aquatic communities and human health, although human health is measured primarily in terms of risks rather than direct health effects. Indicators of the state of aquatic habitats reflect both the condition of the living vegetative component of habitat, and physical and chemical components. Indicators are also used to measure three categories of stress: nutrients, persistent toxic contaminants, and economic activity.

For purposes of simplification, a small number of indicators for each of the background paper subject areas have been chosen and are shown in this paper. These simple indicators are intended to summarize the state of the ecosystem and progress made to date in addressing the many sources of these stresses.

Conditions shown by the indicators are rated in four categories: poor, mixed/deteriorating, mixed/improving and good/restored. The report draws on information from a variety of sources up to the year 1993. Indicators within each of the six subject areas showed a mix of conditions and are summarized in tables beginning on page 21.

The paper concludes with a brief section on challenges for environmental resource managers and decision-makers to consider in the future as they use ecosystem information.

The integration paper is intended to focus and aid discussion among SOLEC participants. The SOLEC Steering Committee welcomes suggestions from participants on how the paper can be improved for post-conference use.

1.0 INTRODUCTION

By almost any standards, the Laurentian Great Lakes Basin (see Figure 1) is rich in resources. The Great Lakes contain one-fifth of all the fresh surface water resources on Earth. The Basin is blessed with extensive forests and wilderness areas, rich agricultural land, hundreds of tributaries and thousands of smaller lakes, extensive mineral deposits, and abundant and diverse wildlife. There are 28 cities with populations of more than 50,000 in the region, and some 32.4 million people call it home. The Basin remains one of North America's major industrial and agricultural regions, is linked by a strong transportation system, and supports a vibrant and growing tourism and travel sector.

Yet with all its riches, the Great Lakes Basin ecosystem is under tremendous stress from human activities. Past and current industrial practices, nutrient loading, resource extraction, urbanization, deforestation, introductions of exotic species, alterations and destruction of natural areas, contamination of air, water and soil — all these stresses, and more, have caused the ecosystem to tip out of balance. What is the state of the Great Lakes Basin ecosystem? This report tries to take a measure of that state.

Restoration and maintenance of the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem is the central purpose of the United States/Canada Great Lakes Water Quality Agreement (GLWQA). Restoration and maintenance can only be achieved with widespread support and action on the part of governments, industry, non-government organizations and the general public. To support this purpose the governments are sponsoring a State of the Lakes Ecosystem Conference (SOLEC).

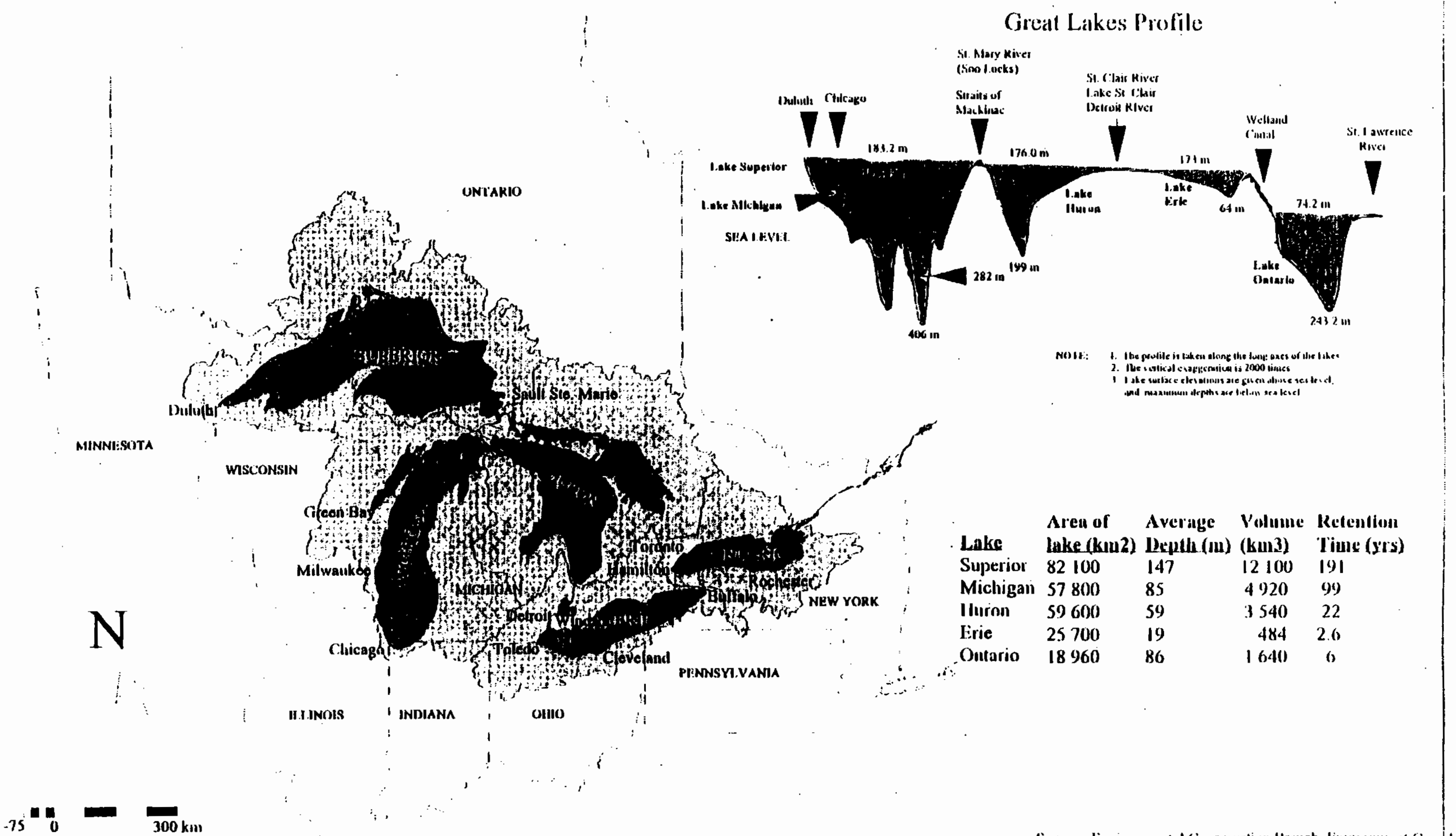
> **"... this first SOLEC is concentrating on recent changes and rates of change. It is recognized that severe impacts have occurred in the past, but the need at this time is to address current conditions, stresses and rates of change."**

A major purpose of the conference is to support better decision-making through improved availability of accurate, ecosystem-based information on the condition of the living components of the system and the stresses which affect them.

Specifically, the conference will:

- provide information on the state of the Great Lakes ecosystem;
- develop support for an integrated system which compiles and distributes environmental information to assist management plans and programs in the Great Lakes Basin;
- provide information on existing Great Lakes management strategies; and
- provide a forum for improved communications and network-building within the Basin.

The Great Lakes Basin



NOTE:
1. The profile is taken along the long axes of the lakes
2. The vertical exaggeration is 2000 times
3. Lake surface elevations are given above sea level, and maximum depths are below sea level

Lake	Area of lake (km2)	Average Depth (m)	Volume (km3)	Retention Time (yrs)
Superior	82 100	147	12 100	191
Michigan	57 800	85	4 920	99
Huron	59 600	59	3 540	22
Erie	25 700	19	484	2.6
Ontario	18 960	86	1 640	6

Source: Environmental Conservation Branch, Environment Canada

FIGURE 1: THE LAURENTIAN GREAT LAKES BASIN

In the interest of focusing attention on decisions that affect the Lakes and gaining wider recognition of the need to consider impacts on the Lakes, this first SOLEC is concentrating on recent changes and rates of change. It is recognized that severe impacts have occurred in the past, but the need at this time is to address current conditions, stresses and rates of change.

As European settlement began almost 400 years ago the Great Lakes were far different than they are today. Compared to their biological diversity at that time and the virtual absence of toxic substances and human pathogens, the Lakes today are severely degraded.

However, some recovery has been made. Most Great Lakes observers would agree that vast improvement has been made in water quality through the control of nuisance conditions, nutrients, human pathogens, and biochemical oxygen demand. Also most observers would agree that much progress has been made in controlling toxic contaminants, although much remains to be done. On the other hand, although some progress is being made on protecting and restoring habitat, losses far exceed gains. In the case of biological diversity, because each loss of genetic diversity is permanent, all losses are additive. Thus while some progress can be made in reducing losses, overall losses of native species and genetic strains will continue faster than that expected in the absence of human activity.

The long-term losses in biodiversity have been severe, as reported in the working paper on Aquatic Community Health. Similarly, losses in habitat have been severe, as reported in the paper on Aquatic Habitat and Wetlands. For both aquatic community health and habitat, while increasing efforts are being made and losses in biodiversity and habitat are slowing, the low point has probably not yet been reached. The hope for habitat is that preservation of habitat essential to high-priority ecosystems will accelerate, together with restoration successes. For biodiversity, its importance is at least becoming widely recognized and steps are being taken to protect endangered species and the ecosystems necessary to support them. Unfortunately each genetic loss is permanent, at least in the time scale of the lives of humans and human civilizations.

For human health, the low point was reached in the late 1800s before adequate treatment was provided for drinking water. In major cities large numbers of people died due to waterborne diseases. Now the risk of such illnesses from pathogens is slight.

While the health of the Great Lakes basin ecosystem declined steeply, the health of the human population seems to have improved dramatically, as measured in longevity, or in the incidence of fatal or crippling infectious diseases such as poliomyelitis or typhoid fever. However, much of that improvement in human health is due to improvements in sanitation, to the development and use of vaccines, and to drinking water disinfection. All of these measures have helped to keep the incidence of severe outbreaks of infectious diseases at a low level. On the other hand, there have been slow, but steady increases in the incidence of certain cancers and of some respiratory illnesses. and we do not know whether or to what extent the many environmental contaminants contribute to these and other human diseases. In addition there are indications that certain kinds of chemical contaminants may interfere with the reproduction and development of animals and humans. These and other signs of possible subtle adverse effects of environmental contaminants on human health need to be investigated further.

This paper has been prepared as a tool to assist managers and decision-makers attending the Conference. Drawing upon the most recent data available, it evaluates the state of the Great Lakes Basin ecosystem. It is hoped that the Paper will focus discussion and spark dialogue among participants about future strategic directions.

This paper is based on six "Working Papers" prepared as background for SOLEC which provide more complete information on the following topics:

- health of aquatic communities;
- human health and health risks;
- aquatic habitat and wetlands;
- nutrients;
- toxic contaminants; and
- economy-environment linkages.

These Working Papers (provided under separate cover) were developed by binational teams with expertise in the relevant issue areas. They provide an account of current and historical conditions in the Great Lakes Basin using a variety of data sources compiled through 1992. They also identify data gaps, suggest priority areas for action, and raise important questions for debate.

This Integration Paper provides information on ecosystem concepts and the Great Lakes ecosystem and describes briefly the changes that have taken place during the last 400 years. It draws from the information presented in the Working Papers to assess the state of the Great Lakes ecosystem today using a preliminary list of ecosystem health indicators. The Paper identifies the major stresses acting on aquatic habitat and aquatic communities, and the major environmental stresses on humans living in the Basin. Interactions among stresses are explored briefly, and the Paper ends with a number of management challenges for the future.

As noted, the Integration Paper is designed to focus and aid discussion among SOLEC participants. The SOLEC Steering Committee welcomes suggestions from participants on how future versions of the Integration Paper can be improved.

2.0 ECOSYSTEM CONCEPTS AND THE ECOSYSTEM APPROACH

Under the binational Great Lakes Water Quality Agreement, an ecosystem is defined as "the interacting components of air, land, water and living organisms, including humans." A number of key ideas are embedded in this concept. These include:

- Humans are part of the ecosystem, and not separate from it.
- Ecosystems can operate and can be defined at many different scales — from global to local — forming a hierarchy of systems nested within systems. The Great Lakes Basin is an ecosystem within which are found five smaller ecosystems — the Lake Superior, Lake Michigan, Lake Huron, Lake Erie and Lake Ontario sub-basins. Within these sub-basins are found rivers draining watersheds, and within these watersheds are found streams draining subwatersheds.
- Ecosystems are not closed systems. Seeds, spores, animals, water, chemicals and nutrients travel between ecosystems or are carried by natural processes and humans. The Great Lakes Basin influences and is influenced by the regions outside of it.
- Ecosystems are dynamic systems in which change is normal and sometimes unpredictable. Over long periods of time, ponds and lakes age and dry up, terrestrial vegetation undergoes succession to reach climax states, and communities adapt to global changes in temperature. Ecosystems can be changed dramatically by natural episodes of fire, flood or glaciation.

> **"Healthy ecosystems have integrity ... but ecosystems also have limits to the stress they can endure. Pushed beyond their ability to absorb or assimilate stress, ecosystems can become degraded."**

Healthy ecosystems have integrity — the resilience to absorb or assimilate external stresses. But ecosystems also have limits to the stress they can endure. Pushed beyond their ability to absorb or assimilate stress, ecosystems can become degraded.

The multiple stresses on Lake Erie are an example. Habitat destruction, sedimentation, over-fishing and nutrient enrichment all contributed to a decline of the fishery and a shift in species composition. Excessive loading of nutrients during the first half of the 20th century lead to a proliferation of algae in the Lake. The breakdown of dead algae by bacteria used up much of the oxygen in the bottom waters of the Central Basin, leaving little for other aquatic life. Due to lack of oxygen, mayflies and their nymphs had vanished from large areas of

Lake Erie, depriving fish species such as perch, walleye, cisco and bass of a staple food. This compounded the already stressed stocks, severely depleted because of the stresses just mentioned.

In the case of the eutrophication of Lake Erie, concerted, basin-wide efforts to reduce phosphorus loadings brought the ecosystem back toward balance again, and aided the restoration of the fishery, already on its way back because of a fishing ban on walleye and whitefish in the early 1970s. In some cases, however, ecosystem effects are irreversible. While ecological restoration can be achieved to some extent, the original aquatic community in Lake Erie with its total biodiversity and genetic diversity within each species can never be recreated. Ecosystem response time is also variable. While surface water can respond to a dramatic reduction in loadings of a particular organochlorine contaminant within a few years, it may take many decades for an equivalent reduction to take place in bottom sediments through natural biological and physical processes.

Governments have traditionally addressed human activities on a piecemeal basis, separating decision-making on environmental quality from decision-making on natural resource management or on social or economic issues. Even within the environmental field, agencies have traditionally managed air issues separately from those dealing with water, land or wildlife. An ecosystem approach to management is a holistic approach that recognizes the interconnectedness of and addresses the linkages occurring among air, water, land and living things. An ecosystem approach:

- includes the whole system, and not just parts of it;
- focuses on interrelationships among the components of the environment and between living and non-living things;
- includes consideration of the natural environment, society and economy;
- is based on natural geographic units such as watersheds;
- incorporates the concepts of sustainability; and
- respects species other than humans and generations other than the present.

The application of the ecosystem approach under the GLWQA has been interpreted in many ways and debate will undoubtedly continue as to how inclusive the concept should be in terms of geographic and socio-economic aspects. In terms of geographic extent, this paper focuses on the conditions in the Lakes themselves and rivermouth areas as influenced by activities throughout the Basin, and not on the conditions in upstream and terrestrial areas. In terms of socio-economic aspects, this report focuses on the state of the biophysical environment, not the state of the social or economic environments. The report considers human health only as it is related to environmental stresses, and does not consider economic health *per se*. However, some major economic stresses are considered to the extent that they impact the biophysical environment.

The ecosystem approach and its applications continue to evolve as better indicators of ecosystem integrity are developed and as management plans and programs are reoriented to produce environmental results measured in terms of ecosystem objectives and indicators. Remedial Action Plans for Areas of Concern and Lakewide Management Plans are leading examples.

3.0 THE STATE OF THE ECOSYSTEM

How healthy is the Great Lakes Basin Ecosystem? What constitutes good health? How can it be measured? The system is clearly different than before European settlement. To what extent has the biological, chemical and physical integrity been lost? What part of the genetic diversity of the system has been lost and how much remains? What modified state of integrity is it possible to attain? Many of these questions can not yet be answered.

The biological state of the Lakes, with the partial exception of Lake Superior, has been unstable during recent decades. What new diverse, self-sustaining, integrated and stable system can reasonably be expected?

One way to determine the status of the Great Lakes ecosystem is to measure indicators of ecosystem health. Doctors use indicators such as blood pressure and weight to gauge human health; economists use indicators such as interest rates and housing starts to assess the health of economies. Ecosystem health indicators measure ecosystem quality or trends in quality that are useful to managers and scientists. Many attempts to develop ecosystem health indicators have been made or are underway in the U.S., Canada and internationally, including those outlined in the Aquatic Community Health working paper.

Because the current attempts to develop indicators of ecosystem health are not at stages where they can readily be used in simple terms, the SOLEC Steering Committee has developed its own preliminary list of indicators (see Table 1). The indicators selected include those for: the state of aquatic communities, human health and health risks, aquatic habitat; and for three categories of stresses — nutrients, persistent toxic contaminants and economic activity. Economic activity is considered to be a stress because the economy of the basin is the basis for most of the activities that are the source of stresses affecting the ecosystem. Of course it is important to recognize that the economy also provides the means to control stresses and restore the system.

The SOLEC Steering and Technical Committees rated the indicators based on information collected for the Working Papers. Rating was done in four broad categories:

- poor, (meaning significant negative impact);
- mixed/deteriorating (meaning that the impact is less severe, but that the trend is towards greater impact);
- mixed/improving (meaning that the impact is less severe, but that the trend is towards less impact); and
- good/restored (meaning that the impact or stress is removed, that the state of the ecosystem component is restored to a presently acceptable level).

3.1 The State of Aquatic Communities

Compared to their chemical, physical and biological integrity 300 years ago, the

Great Lakes ecosystems are extremely unhealthy. The catastrophic loss of biological diversity and subsequent establishment of non-indigenous populations is the most striking indication of degradation of the Great Lakes.

At least 18 historically important fish species have become depleted or have been extirpated from one or more of the lakes. Amplifying this loss of species diversity is the loss of genetic diversity of surviving species. Prior to 1950, Canadian waters of Lake Superior supported about 200 distinctive stocks of lake trout, including some 20 river-spawning stocks. A large number of these stocks is now extirpated, including all of the river spawners. The loss of genetic diversity of lake trout from the other Lakes is even more alarming, with complete extirpation of lake trout from Lakes Michigan, Erie, and Ontario, and only one or two remnant stocks in Lake Huron.

"While aquatic communities in all the lakes have been significantly disturbed and altered by a host of stresses ... those in Lakes Michigan and Ontario are the most unstable."

Accompanying this loss of diversity was a series of invasions and introductions of exotic species. Since the 1880s, some 139 non-indigenous species have become established in the Great Lakes. Together, the non-indigenous species have had a dramatic and cumulative effect on the structure of the aquatic communities of the Great Lakes, and their persistence poses substantial problems for the restoration and maintenance of native species associations.

The state of aquatic communities is the ultimate test of whether prevention, control and restoration programs are effective. Three indicators for measuring the health of aquatic communities were selected. The first indicator — the number of native species lost — was rated as good/restored for Lake Superior, and mixed/improving for the other lakes. As compared to the other lakes, fewer aquatic species have been lost in Lake Superior due to the lower levels of development, industry and human population. Even in the more disturbed lakes, attempts to reintroduce depleted species of native predator fish such as walleye and lake trout have been partly successful.

The second indicator, the Lake Trout Dichotomous Key, provides a measure of how balanced the aquatic ecosystem is. This key is based on scores of questions relating to lake trout and their habitat. Using this indicator, Lake Superior rated as good/restored, Lakes Huron and Erie as mixed/improving, and Lakes Michigan and Ontario as poor. While aquatic communities in all the lakes have been significantly disturbed and altered by a host of stresses (including over-fishing, exotic species, habitat destruction, nutrient enrichment and persistent toxic substances), those in Lakes Michigan and Ontario are the most unstable. U.S. and Canadian government stocking programs to reintroduce lake trout and non-native salmonid predators to the Great Lakes have resulted in the development of popular sports fisheries providing a wide range of species for anglers. The stability of fish communities and fisheries, however, are not predictable at this time.

The third indicator for the state of aquatic communities is reproductive impairment. This indicator is rated as mixed/improving in all lakes. Exposure to a variety of environmental stresses including organochlorine compounds (some widespread, some local) has caused reproductive problems for Great Lakes wildlife, especially aquatic birds. In the 1950s and 1960s severe effects were observed and populations of some species declined, often due to thinning of egg shells. In recent years the problems are present in less obvious forms which cause birth defects or failure to reproduce in a small percentage of the populations. Population problems were sometimes attributable to environmental contaminants, but in other cases populations actually increased during times of high contaminant loadings, e.g. ring billed gulls. Reductions in loadings of organochlorines have allowed populations of herring gulls, Caspian terns, black-crowned night herons and double-crested cormorants to become re-established in the Great Lakes. Indeed, cormorant populations have rebounded to levels never seen before. Continuing low rates of bill defects and other developmental abnormalities were seen through the 1980s in cormorant populations, suggesting that the birds were still being exposed to toxic amounts of PCBs and other organochlorine compounds from fish, particularly in "hotspots" such as Green Bay, Wisconsin. It is worth noting that the "background" frequency of deformities, as determined from Western Canada bird populations, does not differ significantly from the frequency of deformities in most areas of the Great Lakes, except for a few of these hotspots.

While exposure of the aquatic community to most known toxic contaminants is declining, the effect of chronic exposure to low concentrations of persistent toxic substances remains uncertain.

3.2 Human Health and the Effect of Environmental Contaminant Stresses

Environmental contaminants are only one category of factors that affect human health. Other factors include nutrition, adequate shelter, genetic makeup, exposure to bacterial or viral disease agents, lifestyle factors such as smoking, drinking and fitness, social well-being and others.

Because human health reflects the effects of stresses of many kinds from many sources, direct measurement of the effect of any one stress or category of stress is extremely difficult and costly. As a result, most indicators of human health are expressed in terms of health risks attributable to various stresses. A number of factors make it difficult to establish a link between environmental contaminants and human health; these are listed in chapter 4.3.

Direct indicators of human health include the incidence of birth defects and cancer; longevity; children's body weight and development; and incidence of infectious diseases related to water sports and drinking water. Indirect measures include beach closures and fish consumption advisories. Unfortunately, basin-wide data for these measures are not available at this time.

A number of indicators to measure environmental contaminant stresses on humans in the Great Lakes are proposed. These include: water quality; air quality; atmospheric and total radioactivity. Even with measures of stress and exposure, information on differences among basin, national and global levels is limited. In order to better assess the impacts of environmental stresses on human health, better trend data over time must be collected on body burdens, exposures and potential health effects.

> **"... levels of priority contaminants ... in human tissues of Great Lakes residents are similar to levels found in human populations elsewhere ...."**

Available information indicates that levels of priority contaminants such as PCBs, dioxins and furans in human tissues of Great Lakes residents are similar to levels found in human populations elsewhere, suggesting that exposures are also similar.

The overall rating for environmental contaminant stresses from the Great Lakes on human health in the Basin is mixed/improving. Because little data exist to measure impacts of contaminant stresses on humans in the Great Lakes over time, we use the levels of contaminants in the ambient environment and in fish and wildlife and in human milk as a surrogate. Based on this we can reasonably say that the stress from toxic contaminants on human health is likely to be mixed or in some cases improving. This rating reflects the general decline of concentrations of persistent toxic substances in all media including fish throughout the Great Lakes, and the fact that the major route of human exposure to contaminants in Great Lakes waters is through fish consumption.

3.3 The State of Aquatic Habitat

The first indicator selected for the state of aquatic habitat and wetlands is the loss of habitat (both in terms of quality and quantity) which was given a rating of poor. Loss of wetlands in the U.S., loss of coastal wetlands in Ontario, and loss of brook trout habitat in the Lower Lakes were all considered evidence of poor conditions. Wetland losses, in particular, have been significant across the Basin. Studies show that in some areas up to 100% of coastal wetlands in Lakes Ontario, Erie, Michigan and St. Clair have been lost to development. Losses of total wetlands (including both coastal and inland wetlands) have been staggering. Sixty percent of the original wetlands in the Great Lakes Basin States have been lost since the 1780s; in Ontario, south of the Precambrian Shield, wetland losses have been estimated to be as high as 80%. While losses continue, current rates of loss are unknown, as are rates of impairment. In many cases, wetlands may still appear to exist but may be functionally degraded through siltation, nearby development, the introduction of foreign plants and animals, and other stresses. Few data exist on the magnitude of losses for other critical habitats such as rocky shoals, sheltered bays, estuaries and tributaries.

In contrast, the indicator for loss of brook trout stream habitat in the Upper Lakes was rated as good/restored. Fewer cold-water streams have been lost and degraded in the Upper Lakes basins because of the lower degree of urbanization and human disturbance.

> **"Sixty percent of the original wetlands in the Great Lakes Basin States have been lost since the 1780s; in Ontario, south of the Precambrian Shield, wetland losses have been estimated to be as high as 80%."**

A second indicator — encroachment and development of wetlands — was also rated as poor. This reflects the continuing loss and degradation of wetlands basin-wide due to urban development, recreational uses, agriculture and other forms of encroachment.

The third indicator selected considered gains in habitat and wetlands through protection, enhancement and restoration efforts. There are various international, national and state/provincial policies and programs for habitat/wetlands protection, some of which rate quite high in results. However, the net effect of protection, enhancement and restoration is considered to be poor since programs are not keeping up with habitat losses. An example of a program producing good results is the North American Wildlife Management Program which has resulted in the protection of more than 17,500 hectares of wetlands in the Basin.

3.4 Nutrient Stresses

Four indicators to measure nutrient stresses were rated. Three were rated as good/restored. Two of these are total phosphorus loadings (GLWQA targets were achieved by 1991 in four of the five Lakes) and total phosphorus concentrations in open water (GLWQA objectives were achieved by 1991 in all Lakes). A third "good/restored" rating was given to an indicator measuring the levels of chlorophyll a in the Lower Lakes, which is a surrogate for the productivity of the system (the amount of algae growth). The low level of chlorophyll a found today is consistent with the GLWQA goal set in 1972 of "reduction in the present level of algal biomass to a level below that of a nuisance condition."

The fourth indicator — levels of dissolved oxygen in Lake Erie's bottom waters — was considered mixed/improving. Oxygen levels in Lake Erie's bottom waters are much better than they were twenty years ago. Notwithstanding this, and despite phosphorus loading reductions, periods of anoxia (lack of oxygen) were still occurring from 1987 to 1991 in the late summer in some areas of the

Central Basin. This continued anoxia may be attributable to the release of historical phosphorus from bottom sediments, or, it may be that intermittent anoxia is an inherent property of Lake Erie's Central Basin.

3.5 Persistent Toxic Contaminant Stresses

To measure the effects of stress from persistent toxic contaminants, three indicators were selected: loadings of persistent toxic contaminants, levels of chemical contaminants in fish and levels in herring gulls. Each of these indicators is considered as mixed/improving. Levels of persistent toxic contaminants have been reduced substantially since 1970 (see Figure 2 showing dioxin concentrations in herring gull eggs from 1971 to 1992). As to reductions in loadings of persistent toxic substances, detailed figures are not available basin-wide, but the ecosystem response over time can be seen in media such as open waters, sediments, fish and wildlife.

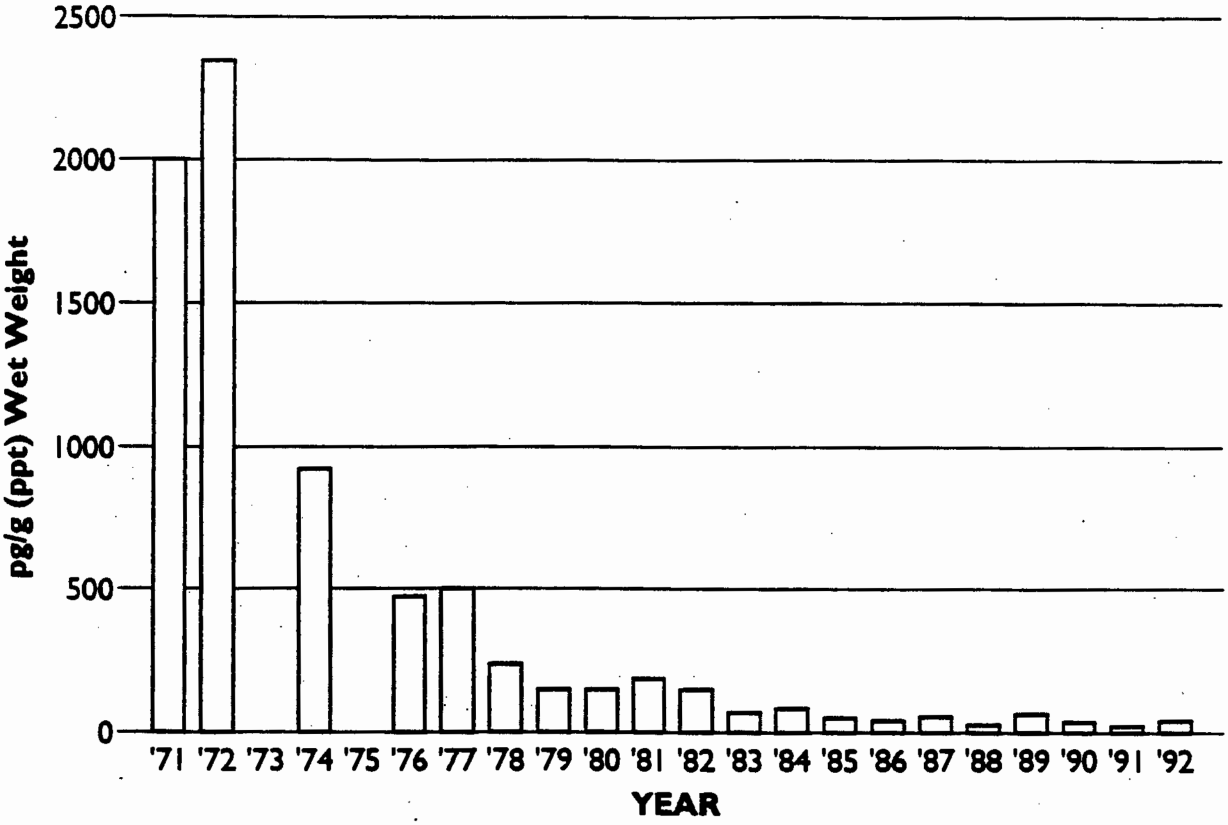
> **"... although large percentage reductions have been achieved in comparison to peak levels, for many contaminants, an additional level of magnitude further reduction is needed to reach acceptable levels of risk."**

Levels of organochlorine contaminants in the tissues of top predator and forage fish initially declined significantly from the late 1970s to mid 1980s but have shown a slower rate of decline recently. Despite this overall trend, from 1986 to 1989, in some areas, particularly in Lake Ontario, levels of some of these contaminants increased in some fish. On the other hand, from the late 1970s to the mid 1980s, concentrations of heavy metals showed little change. Levels of persistent toxic contaminants in some fish species in some areas continue to be high enough to restrict consumption by humans.

One possible cause of these continuing high levels is that contaminant concentrations in fish are influenced by changes in food which varies in availability and contaminant content. As a result, changes in contaminant levels in fish may be influenced by shifts in feeding behavior by fish or elsewhere in the food web.

Overall, contaminant levels have shown good response to control programs although the rate of response has slowed. Although overall contaminant levels have been substantially reduced from peak levels, for many contaminants, additional reductions (in the order of a level of magnitude) are needed to reach acceptable levels of risk. Also, as more is learned about long term exposure and endocrine effects, even lower levels may be required to reach acceptable risk.

Chemical residues in herring gull eggs have been monitored by the Canadian Wildlife Service since 1974. All the chemicals routinely monitored since then (including PCBs, DDT/DDE, mirex, dieldrin and HCB) have shown a statistically



Data Source: Weseloh, 1993

FIGURE 2: DIOXIN (2,3,7,8-TETRACHLORO-DI-BENZO-DIOXIN) CONCENTRATION IN HERRING GULL EGGS 1971-1992, EASTERN LAKE ONTARIO

significant decrease at more than 80% of the sites sampled. Chemicals monitored later in the program, such as oxy-chlordane, photo-mirex, and 2,3,7,8-TCDD, have also shown significant decreases. The greatest decrease observed occurred between 1974 and 1981; since then the rate of decrease has slowed and levelled off. In 1991-1992, increases in the level of certain contaminants have been noted in some locations. The reasons for this apparent increase are not known, and may be linked to changes in diet due to changes in the food web.

3.6 Economic Stresses and Mitigating Activity

Economic activity produces both stresses on the ecosystem and the means to address or mitigate them.

Ten economic indicators were selected. Two of these were rated as poor: infrastructure investment and loss of agricultural land and urban development. This rating reflects the continuing low levels of government investment in basic infrastructure (with the exception of some $10 billion U.S. in sewage treatment plant construction and sewer system upgrades during the past two decades), and the continuing trend to urban sprawl.

Four economic indicators were rated as mixed/deteriorating — employment; research and development; personal income; and population growth and stability. For the years 1970 to 1990, employment growth in the Basin lagged behind that experienced overall by the U.S. and Canada. During this period, total U.S. employment grew at 53% while employment in the U.S. side of the Basin grew at only 25%. Similarly, total Canadian employment during this time period grew at 15%, while employment in the Canadian side of the Basin grew by only 6%. In recent years, personal income growth in the Basin has slowed substantially, reflecting the loss of manufacturing jobs and increase in service sector employment. From 1970 to 1980, personal income in the Basin grew by 140%; that for 1980 to 1990 grew at only 83%. The population of the Basin grew by less than 1% from 1970 to 1990, as compared to the combined population of the U.S. and Canada which grew by 22% over the same period. While urban sprawl clearly adds stress, population and economic growth add stress and also provide the means to control both new and old stressors.

> **"Strategies for a sustainable future must try to correct the past imbalance between the economy and the environment, and apply ecosystem management principles and sustainable development policies in the future."**

Four indicators — pollution prevention, adoption of a stewardship approach, water conservation, and per capita energy use — were rated as mixed/improving, reflecting changing public attitudes towards resource conservation and sustainable development. Increasing public concern about environmental issues and aggressive environmental regulation have focused attention on environment-economy linkages and on the concept of sustainable development. Strategies for a sustainable future must try to correct the past imbalance between the economy and the environment, and apply ecosystem management principles and sustainable development policies in the future. Recognition of economic-environmental linkages in resource management and protection is increasing throughout the Great Lakes Basin. However, the leap between the concept of sustainable development and its application is a formidable one.

3.7 Overall Health of the Great Lakes Basin Ecosystem

Overall, the health of the Great Lakes Basin Ecosystem is variable, depending on the measurement used. By some measures, the health is good/restored; this is certainly so for the aquatic community on Lake Superior. At the other end of the spectrum, a number of indicators show quite clearly that some aspects of ecosystem health are poor. These include habitat loss, encroachment and development of wetlands, and the imbalance of aquatic communities in Lakes Michigan and Ontario. In between the extremes, as we have seen, many indicators are mixed, with some trends improving and others deteriorating.

TABLE 1: PRELIMINARY INDICATORS OF ECOSYSTEM HEALTH

INDICATORS	**STATUS OF INDICATORS**			
	Poor	Mixed/ Deteriorating	Mixed/ Improving	Good/ Restored
STATE OF AQUATIC COMMUNITIES				
1. Native Species Loss (# of native species)				
Lake Superior				✓
Lakes Huron, Michigan, Erie & Ontario			✓	
2. Ecosystem Imbalance (Lake Trout Dichotomous Key)				
Lake Superior				✓
Lakes Huron & Erie			✓	
Lakes Michigan & Ontario	✓			
3. Reproductive Impairment				
Effects – all Lakes			✓	
Body burdens – all Lakes			✓	
HUMAN HEALTH AND ENVIRONMENTAL CONTAMINANT RISKS				
Overall state			✓	
1. Air/water/soil/sediment contamination • contamination trends (O_3, SO_4, dust) • hospital admission and death rates for respiratory illness rates (e.g. asthma) • beach closings • infectious diseases related to recreational uses • atmospheric and total radioactivity	–	–	–	–
2. Fish consumption advisories • contaminant loadings	–	–	–	–
3. Human contaminant body burdens	–	–	–	–
4. Measurements of health status/health effects • birth defects and cancer • longevity • children's body weight/development	–	–	–	–

Dashes indicate lack of Basin-wide data

TABLE 1: PRELIMINARY INDICATORS OF ECOSYSTEM HEALTH (continued)

INDICATORS	STATUS OF INDICATORS			
	Poor	Mixed/ Deteriorating	Mixed/ Improving	Good/ Restored
STATE OF AQUATIC HABITAT AND WETLANDS				
1. Loss in habitat/wetlands quality & quantity				
United States – Michigan Survey	✔			
– other states	✔			
Ontario – CWS coastal wetlands	✔			
– Brook Trout stream habitat (Upper Lakes)				✔
– Brook Trout stream habitat (Lower Lakes)	✔			
2. Encroachment/development Basin-wide	✔			
3. Gains in habitat/wetlands quality & quantity				
Areas protected under the North American Wildfowl Management Plan				✔
Net effect	✔			
NUTRIENT STRESSES				
1. Total phosphorus loads • targets achieved in 4 of 5 Lakes (1991)				✔
2. Total phosphorus intake concentrations • objectives achieved in all Lakes (1991)				✔
3. Lake Erie dissolved oxygen (Central Basin hypolimnion)			✔	
4. Chlorophyll a (as indicator of nuisance algal growth) in Lower Lakes				✔
CONTAMINANT STRESSES				
1. Loadings			✔	
2. Residue in fish			✔	
3. Residue in birds (herring gulls)			✔	
4. Body burdens – all Lakes			✔	

TABLE 1: PRELIMINARY INDICATORS OF ECOSYSTEM HEALTH (continued)

INDICATORS	STATUS OF INDICATORS			
	Poor	Mixed/ Deteriorating	Mixed/ Improving	Good/ Restored
ECONOMIC STRESSES AND MITIGATING ACTIVITY				
1. Employment (manufacturing & other sectors)		✓		
2. Infrastructure investment (public & private sectors)	✓			
3. Research & development (measures of technological innovation)		✓		
4. Land-use and reuse changes (loss of agricultural land & urban development)	✓			
5. Population growth and stability (compared to other regions)		✓		
6. Pollution prevention (expenditures and results - loadings/emissions/discharges)			✓	
7. Personal income (statistics)		✓		
8. Adoption of stewardship approach (public & private sectors)			✓	
9. Water conservation (industry & per capita)			✓	
10. Energy use (per capita)			✓	

4.0 MAJOR STRESSES AND THEIR INTERACTIONS

4.1 Major Stresses on Aquatic Communities

Great Lakes aquatic communities continue to be exposed to a multiplicity of physical, biological and chemical stresses. In terms of importance, the major stresses on aquatic communities are:

- imbalances in aquatic communities and loss of biodiversity due to over-fishing and fish stocking, and presence of exotic species;
- degradation and loss of tributary and nearshore habitat;
- impacts of persistent toxic contaminants; and
- eutrophication in localized areas.

Imbalances in Aquatic Habitat and Loss of Biodiversity

Although physical and chemical stresses have contributed to the decline in integrity of Great Lakes' ecosystems, stresses associated with biological factors have, in fact, caused much more severe degradation. In particular, over-fishing and introduction of exotic species have had tremendous impacts on aquatic communities, causing profound changes and imbalances.

The loss of biodiversity and concomitant establishment of non-indigenous populations in the Great Lakes has been little short of catastrophic. The history of the Great Lakes and the collapse of its commercial fisheries offer dramatic examples of the effects of over-fishing. Native top predators, once dominated by lake trout, have been replaced by hatchery-reared imports. Table 2 lists the many species of Great Lakes fish that have been extirpated or are severely depleted due to human activities, mostly over-fishing. What is not shown by the table is the fundamental loss of genetic diversity among surviving species.

> **"The loss of biodiversity and concomitant establishment of non-indigenous populations in the Great Lakes has been little short of catastrophic."**

Accompanying (and sometimes accelerating) this loss of diversity was a succession of invasions and deliberate releases of exotic aquatic species. Some 139 non-indigenous aquatic species have become established in the Great Lakes since the 1880s. Species that have established substantial populations include: sea lamprey; alewife; smelt; gizzard shad; white perch; carp; brown trout; chinook, coho and pink salmon; and rainbow trout. To this list can be added more recent imports such as the zebra and quagga mussel, ruffe, rudd, fourspine stickleback and others, and plant species such as purple loosestrife. Together, these species have had a dramatic and cumulative effect on the structure of aquatic communities in the Great Lakes. The continuing presence of these non-indigenous species

TABLE 2. SUMMARY OF FISH SPECIES LOST OR SEVERELY DIMINISHED BY LAKE IN THE GREAT LAKES. AN ASTERISK (*) INDICATES STOCKING PROGRAMS EXIST TO ATTEMPT RE-INTRODUCTION. STATUS CODES ARE 1 (DEPLETED), 2 (EXTIRPATED), AND 3 (EXTINCT).

Common	Species Name	Lake Superior	Lake Huron	Lake Michigan	Lake Erie	Lake Ontario
Lake sturgeon	*Acipenser fluvescens*	1	1	1	1	1
Longjaw cisco	*Coregonus alpenae*		2	2	2	
Lake herring	*C. artedii*	1		1	2	
Lake whitefish	*C. clupeaformis*				1	
Bloater	*C. hoyi*					2
Deepwater cisco	*C. johannae*		2	2		
Kiyi	*C. kiyi*	1	2	2		2
Blackfin cisco	*C. nigripinnis*	2	2	2		2
Shortnose cisco	*C. reighardi*		2	1		1
Shortjaw Cisco	*C. zenithicus*	1		2		
Burbot	*Lota lota*					1
Fourhorn Sculpin	*Myoxocephalus quadricornis*					3
Emerald shiner	*Notropis atherinoides*			2	1	
Atlantic salmon	*Salmo salar*					2*
Lake trout	*Salvelinus namaycush*		2*	2*	2*	2*
Sauger	*Stizostedion canadense*				2	
Blue pike	*S. vitreum glaucum*				3	3

poses substantial problems for the rehabilitation and maintenance of native species associations.

Habitat Degradation and Loss

It is difficult to overestimate the importance of adequate and diverse aquatic habitat for healthy aquatic communities — it is simply the most basic building block of ecosystem health. Without adequate habitat in which to spawn, breed, nest, stopover, forage and hide, many species of fish and wildlife cannot survive. In Lakes Ontario and Michigan, and to a lesser extent in Huron and Superior, stocking of predators obscures the effects of degraded habitat: the lack of spawning areas, for example, becomes less obvious. In highly polluted areas of the Great Lakes, fish communities may have already compensated for these effects by restructuring and eliminating tributary-dependent stocks. Lack of basin-wide data on the amount and quality of aquatic habitat is a major barrier to measuring habitat health, quantifying habitat status, and rehabilitating aquatic communities. Ensuring the health of aquatic habitats and wetlands is a priority concern for ecosystem health in the Basin, and will require a greater share of resources than it has been receiving to date.

Persistent Toxic Substances

Persistent toxic contaminants have had an impact on fish and wildlife species in the Basin. Observed effects include alteration of biochemical function, pathological abnormalities, tumors, and development and reproductive abnormalities. Recent studies have suggested that estrogenic effects of some organochlorines are implicated in developmental abnormalities in wildlife species. A possible consequence of the above effects is a decrease in fitness of populations. In fish, however, it is difficult to link cause (i.e. exposure to one or more toxic contaminants) to effects. There are some laboratory studies and evidence by association that tumors in Great Lakes bullheads and suckers (both bottom feeders) may be caused by contaminated sediments. In general, however, the effects of exposure to low levels of contaminants are less clear for fish populations than for wildlife in the Basin. For a list of priority contaminants see Table 3.

Various studies have identified contaminant-associated effects on 11 species of wildlife in the Great Lakes. Affected species include fish-eating mammals (mink and otter), reptiles (snapping turtle), and fish-eating birds (double-crested cormorant, black-crowned night heron, bald eagle, herring and ring-billed gull, and caspian, common and Forster's terns). All of these but the ring-billed gull and otter showed historical evidence of reproductive impairment due to contaminants. Populations of fish-eating birds declined dramatically throughout the 1960s and 1970s as a result. With the reduction in loadings of persistent toxic contaminants such as PCBs, most of these bird populations recovered. The reproductive success of breeding eagles eating Great Lakes fish remains lower than that of those nesting inland. However, recovery of the bald eagle to pre-1950 levels is likely limited by the absence of appropriate habitat, and may be limited by food supply. Substantial parts of the Lake Erie shoreline, and substantial portions of the shorelines of Lakes Ontario, Michigan and Huron are not suitable habitat for the bald eagle because of agriculture, urban sprawl and human disturbance. As indicated in chapter 3.0, continuing low rates of bill defects and other developmental abnormalities were seen through the 1980s in cormorant populations, suggesting that the birds were still being exposed to excessive amounts of PCBs and other organochlorines from fish, particularly in "hotspots" such as Green Bay, Wisconsin.

Eutrophication

Although eutrophication is no longer a problem in the Great Lakes on a lake-wide basis, it continues to occur in local areas and has a moderate impact on aquatic communities. This is particularly of concern in coastal marshes and inland wetlands. Nutrient enrichment causes

TABLE 3: PRIORITY CONTAMINANTS OF THE GREAT LAKES

CHEMICAL	REFERENCE
Aldrin	1,5,7
Benzo(a)pyrene	1,3,5,7,8
Chlordane	1,2,3,6,7
Copper	1,2,3
DDT and metabolites	1,2,3,5,6,7
Dieldrin	1,2,3,6,7
Furan	1,3,5,7
Heptachlor	1,2,3
Heptachlor epoxide	1,3
Hexachlorobenzene	1,2,3,5,6,7
Alkylated Lead	1,3,4,5,7
α Hexachlorocychlohexane	1,3,8
ß Hexachlorocyclohexane	1,3,8
Mercury	1,2,3,4,5,6,7
Mirex	1,3,5,7
Octachlorostyrene	1,3,6,7
Polychlorinated biphenyls	1,2,3,5,6,7
2,3,7,8-TCDD (dioxin)	1,2,3,5,6,7
Toxaphene	1,2,3,5,6,7

References:
1 = GLWQA Annex 1, list 1 (173 total pollutants in list)
2 = GLWQI guidance list of 33 pollutants
3 = LAMPS critical pollutants lists (Lake Michigan 15 total, Lake Ontario 9 total)
4 = Pollution Prevention (Industrial Toxics Project, 17 total)
5 = Eleven Critical Pollutants (1985 IJC Report)
6 = Lake Superior Binational Initiative (9 total)
7 = Canada-Ontario Agreement Tier 1 list of 13 virtual elimination contaminants
8 = Canada-Ontario Agreement Tier 11 list of 26 (including 17 PAHs)

excess growth of algae which depletes the water column of oxygen needed to sustain other forms of aquatic life.

4.2 Major Stresses on Aquatic Habitat

Wetlands, tributaries, connecting channels, open lakes and nearshore areas of the Great Lakes each play a vital role in ecosystem function. The ultimate health of the Great Lakes ecosystem is strongly dependent on the health, availability and capacity of these components.

A number of different classification systems exist for aquatic habitat. For the purposes of this paper, habitats can be divided into the following types:

- open-lake;
- inshore (including coastal wetlands, rocky shoals, sheltered bays and estuaries);
- shoreline (including sand dunes, beaches, gravel shores and lakeplains);
- tributaries (those rivers and streams that drain into the Great Lakes);
- connecting channels; and
- inland habitats (including fens, bogs, marshes, wet meadows, ponds and lakes).

Aquatic habitats function in many important ways. They play a vital role in nutrient cycling, uptake and transfer. They are among the most productive of systems in terms of the growth of photosynthetic organisms (the assimilation of energy by plants). Aquatic habitats help to maintain water quality and regulate water flows and levels. They play important, sometimes very specific roles in the life cycles of mammalian, aquatic and avian species, providing habitat for spawning, nesting, rearing, foraging and sheltering. Aquatic habitats provide a significant proportion of the total biodiversity of the Great Lakes Basin Ecosystem. Amongst all types of aquatic habitats, the inshore zone (and its wetlands) ranks highest in terms of performing these functions.

"Physical alteration of aquatic habitat has been the greatest cause of habitat loss in the inland, shoreline and inshore zones of the Great Lakes."

Basin-wide data on the quality and quantity of aquatic habitats are scarce and fragmented, and the best information that exists is for wetlands. A U.S. National Wetlands Inventory is now being developed which will map wetlands survey information, now only broken down by state or province, on the basis of drainage basins. Environment Canada, in cooperation with other agencies and groups, is gathering habitat-related information through a number of programs. Notwithstanding these initiatives, quantifying habitat status remains largely descriptive and anecdotal, and there are no accepted basin-wide classification systems that integrate all aquatic habitat types and allow habitat health to be easily measured.

The major stresses acting on aquatic

habitat in the Great Lakes can be divided into five categories. In terms of importance (i.e. magnitude of effect) these are:

- physical alteration (filling, channelization, dredging, bulkheading, etc.)
- hydrological changes (alterations in water levels and flows, loss of connectivity)
- physical process changes (temperature changes, sedimentation)
- biological changes (addition of exotic species)
- chemical changes (addition of nutrients, persistent toxic substances)

Physical alteration of aquatic habitat has been the greatest cause of habitat loss in the inland, shoreline and inshore zones of the Great Lakes. Such alterations as lakefilling in urban areas, dredging, building dock walls in harbors, and the channelization of rivers eliminate the highly productive shallow water habitat that is particularly crucial to forage fish species and wading birds. Filling and draining of wetlands for agricultural or urban use eliminates not only the habitat, but the invertebrate, fish and amphibian populations living in that habitat. The development of shorelines and riverbanks for private docks, cottages and housing, and the building of bridges usually can degrades nearshore habitat.

Hydrological changes can have serious effects on inland wetlands, tributaries, inshore and shoreline habitats. Alterations in levels and natural fluctuations of the Great Lakes can have severe impacts on coastal marshes by flooding out or drying up vegetation. Unnatural stream flows can be caused by poor stormwater management which causes flushing of vegetation, sedimentation and erosion. Overconsumption of groundwater leads to reductions in base flows in streams, so that insufficient water is present for fish spawning. Wetlands which are hydrologically disconnected from their sources of water (e.g. coastal wetlands cut off from a lake) will degrade and dry up.

Physical process changes that can affect aquatic habitat include temperature changes due to the removal of bankside vegetation, and increased sedimentation. Temperature increases in a headwater stream will eliminate habitat for coolwater species such as brook trout. Sedimentation covers fish spawning beds, rendering them unusable, and suspended sediment limits plant growth. Sediment-laden river beds also provide ideal habitat for sea lamprey (ammocoetes) in their life cycle prior to becoming parasitic.

Biological changes have had a profound effect on aquatic habitat in the Great Lakes. The introduction of sea lamprey, carp, purple loosestrife, zebra and quagga mussels, the ruffe and other foreign species has had a significant impact on aquatic habitats, but the scope of the impact is not yet well-understood. Both zebra and quagga mussels, for example, eat organic detritus. In Lake Erie, this has resulted in the extinction of native Unionidae clams, and may be contributing to declines in stocks of smelt, yellow and white perch.

Chemical changes are moderate threats to aquatic habitat. The major chemical changes are excessive nutrients and the presence of toxic substances. Eutrophication continues to be a localized problem in tributaries and inshore habitats in many of the Areas of Concern. Increased controls have reduced inputs of toxic compounds from industries and municipalities, but loadings continue from urban and agricultural run-off and releases from contaminated sediments already in the system.

4.3 Major Environmental Contaminant Stresses on Humans

Hundreds of chemicals have been identified as being present in the Great Lakes ecosystem. Of these, the IJC has identified 11 as critical pollutants, based on: 1) presence in the Great Lakes environment; 2) degree of toxicity; 3) persistence; and 4) ability to bioconcentrate and bioaccumulate. These 11 substances are listed in Table 3 together with several others identified for priority consideration. While these are recommended for priority consideration, there are numerous other substances which must also be considered due to their known or suspected impact on the ecosystem and human health.

> **"While there is a large volume of scientific evidence to show that these agents are harmful, it is not certain how much harm they are causing to the inhabitants of the Great Lakes Basin."**

There are a number of pathways by which humans in the Great Lakes Basin can be exposed to persistent toxic contaminants. The major route of human exposure to PCBs, dioxins, furans, organochlorine pesticides and certain heavy metals is food consumption, particularly consumption of contaminated fish. Food is believed to contribute from 40% to nearly 100% of total human intakes for many of these substances. Studies of fish eaters in the Great Lakes Basin have shown a correlation between sport-caught fish consumption and body burden of PCBs and DDE in blood and serum. Other routes of exposure include drinking water, breathing contaminated air, and dermal exposure. For contaminants other than toxics, such as microbes, the major routes of exposure for humans are through poorly treated drinking water and recreational activities such as swimming. An example of microbial problems is the protozoan *Cryptosporidium* which has recently caused intestinal problems, including some deaths, due to its presence in drinking water.

Human populations in the Great Lakes basin, like those living elsewhere, are exposed to many toxic pollutants present in the environment. Those of particular concern in relation to the GLWQA include dioxins and furans, organochlorine pesticides and their byproducts such as hexachlorobenzene, combustion byproducts such as polycyclic aromatic hydrocarbons (PAHs), and certain metals and their compounds such as cadmium, lead, and mercury. Other contaminants include radioactive elements such as radon and air contaminants such as ozone.

While there is a large volume of scientific evidence to show that these agents are harmful, it is not certain *how much* harm they are causing to the inhabitants of the Great Lakes Basin. There are several reasons for this uncertainty. One reason is the surprising scarcity of suitable health statistics (indicators) to show the spatial and temporal trends of the state of health of various Great Lakes populations relative to that of people living elsewhere. Suitable data are lacking, for example, on the "normal" growth and physical and mental development of children, on the general state of health and longevity of people living in various regions, on the number of people seeking treatment for infectious diseases caused by contaminated recreational or drinking water, and on the number of people admitted to hospitals for ill effects caused by exposure to chemical environmental contaminants. Reliable statistics on the occurrence of birth defects or cancers are lacking for some regions of the Basin. It is also difficult to ascertain exposure (i.e. to what kinds of contaminants and to what levels people are exposed). A large number of contaminants occur at low concentrations, some of which may gradually accumulate in the body; others are excreted without leaving a trace, although they may have done some damage.

A number of factors make it difficult to establish a link between environmental contaminants and human health effects. These include:

- the continuous nature of exposure over many years to low levels of contaminants;
- exposure to mixtures rather than individual compounds;
- the large number (and in some cases poor definition) of health effect endpoints to be examined, and the difficulty of measuring some effects;
- experimental design problems (including the inability, in some cases, to obtain adequate sample sizes and measurements that are suitably sensitive and specific to detect changes);
- dose-response questions;
- accurate exposure assessment; and
- confounding variables that may hinder research studies.

In the past, health researchers and policymakers have tended to focus on dramatic episodes accompanied by obvious health effects such as massive spills of chemicals, or smog episodes, and on the most serious kinds of health effects such as cancer. Recent scientific evidence, however, based mostly on observations in animals, raises concerns that exposure to low levels of certain contaminants may cause subtle reproductive, developmental and physiological effects that may go easily unnoticed, but which in the long term may lead to serious cumulative damage. This includes such effects as immunotoxicity, neurotoxicity, so-called hormone mimicry, subtle pre- and postnatal developmental effects, and decreased fertility. In trying to assess the effects of contaminants on human health, the U.S. and Canadian governments have moved to use a so-called "weight of evidence" approach which relies on information from many sources, including data on animals as well as humans. This allows educated guesses to be made which can then be tested through appropriate medical and scientific studies.

4.4 Key Interactions Among Stresses

As outlined in Chapter 2, an ecosystem can be defined as the interacting components of air, water, land and living organisms, including humans. While the notion of the ecosystem approach has been embedded in the GLWQA since 1978, policymakers have only relatively recently begun to grapple with actually using the ecosystem approach in planning. One of the challenges of the ecosystem approach is that it requires a focus on *interactions* and *linkages*, as distinct from more traditional environmental approaches in which thinking tended to be compartmentalized.

> **"One of the challenges of the ecosystem approach is that it requires a focus on interactions and linkages, as distinct from more traditional environmental approaches in which thinking tended to be compartmentalized."**

Because an ecosystem such as the Great Lakes ecosystem is so complex, understanding the interactions between actions and effects is not easy. Like a pond into which a stone is tossed, seemingly innocent actions can have ripple effects that are cumulative, indirect, and far-reaching. Figure 3 is a simplified diagram that attempts to illustrate some of the linkages among major ecosystem stresses and the environment. The diagram illustrates only the biophysical (natural) environment, and accordingly does not include important social and economic aspects of the ecosystem. It shows the major linkages among three components of the environment (human communities, aquatic habitat and aquatic communities) and three key stresses (nutrients, toxic contaminants and exotic species).

The figure shows the major activities that cause stress on the Great Lakes ecosystem. These include: nutrient and contaminant loading, introduction of exotic species, over-fishing and stocking, and physical and hydrological impairment of aquatic habitat. Physical impairment of habitat includes lakefilling, dredging, channelization, deforestation, sedimentation and other stresses. Hydrological impairment includes loss of hydrological connectivity and alterations in water levels and flows.

As can be seen from Figure 3, not only do these human activities put stress on aquatic communities and aquatic habitat, they also cause stress on human communities. Discharging toxic contaminants into the environment, for example, potentially exposes humans to these contaminants through air, drinking water, eating fish and other food grown within the Basin, and swimming and other water sports. This illustrates a fundamental

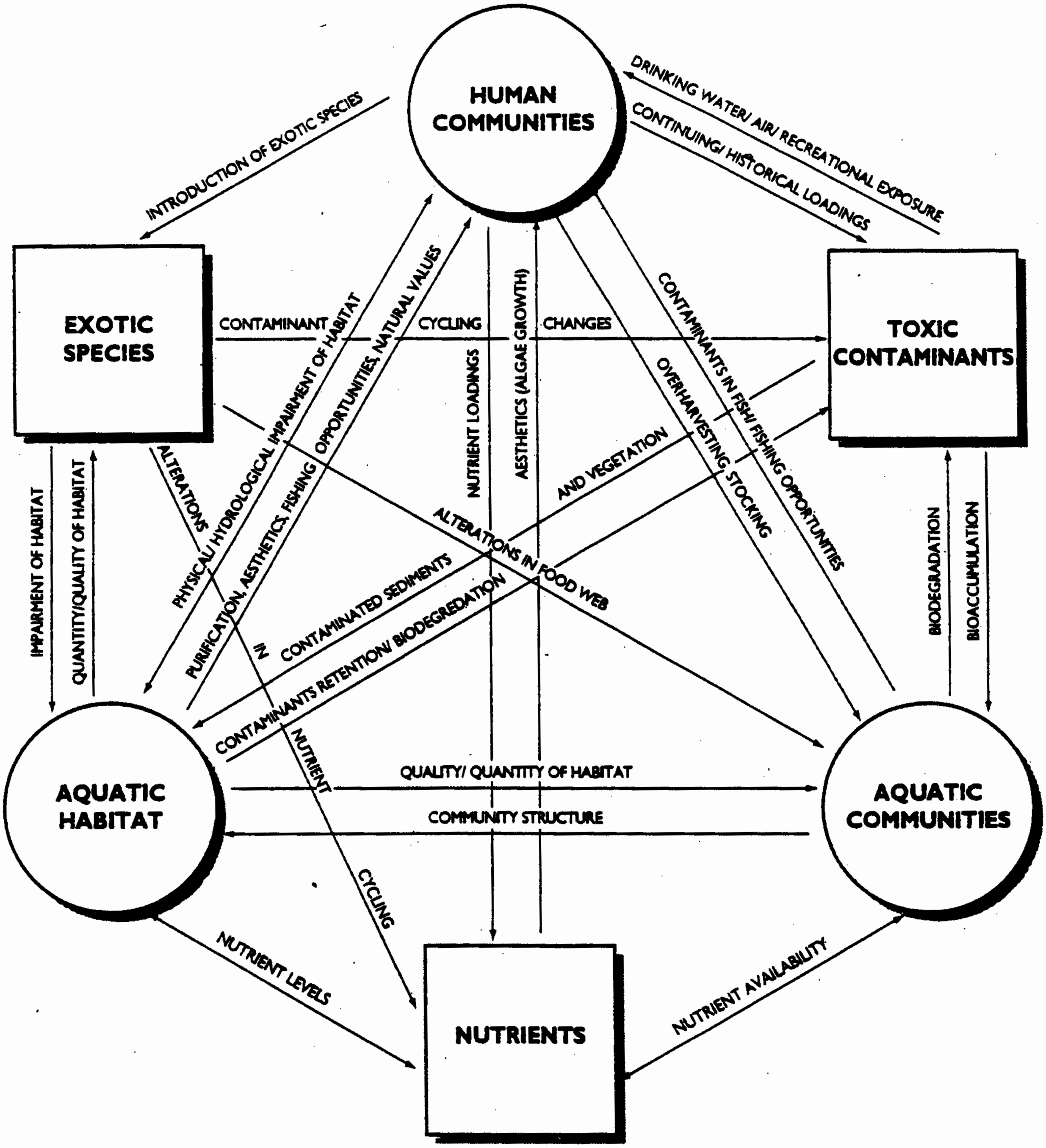


FIGURE 3: PRIMARY BIOPHYSICAL STRESSES ON THE GREAT LAKES ECOSYSTEM AND THEIR LINKAGES

tenet of the ecosystem approach, one that sets it apart from conventional environmental planning — humans are part of the ecosystem, not separate from it.

Loss of Aquatic Habitat

Figure 3 also shows how an environmental problem such as loss or degradation of aquatic habitat can have many causes. Habitat loss and impairment can be caused by a host of stresses — physical alterations, hydrological changes, the introduction of exotic species, the presence of toxic contaminants, high levels of nutrients and changes in community structure. These stresses can operate individually or in concert. In practice, aquatic habitat in the Great Lakes will usually be exposed to more than one of these stresses. This illustrates a fundamental aspect of ecosystem health — because ecosystems are so complex, effects are rarely caused by only one stress.

Figure 3 also illustrates how one "problem" can have many different consequences. As an example, aquatic habitat loss and impairment will have a direct impact on the health of aquatic communities. Loss of spawning or foraging areas for pike, for example, will directly affect the ability of that species to survive locally, and will in turn affect forage fish populations and other parts of the food web. Habitat loss and impairment can have negative impacts on human communities because of accompanying loss of aesthetic and natural values, and reduced opportunities for sport and commercial fishing. Wetland loss and impairment, in particular, contributes to higher loadings of nutrients and contaminants in the Great Lakes ecosystem because of decreased contaminant retention and biodegradation. And these higher levels of contaminants in the system will increase the potential exposures to humans. This example illustrates the complex interrelationships that lie at the heart of the ecosystem approach: at first glance, paving over a wetland seems far-removed from increased human exposures to contaminants, but the connections are indeed there. The next section provides some more examples of the many complex interactions and linkages that characterize the Great Lakes ecosystem and that challenge managers.

Contaminant Cycling

One of the important linkages that is not directly illustrated by Figure 3 is how contaminants can move through the Great Lakes Basin ecosystem (and into the Basin from outside). The ecosystem approach tells us that "everything is connected to everything else." A PCB molecule discharged into Lake Ontario, for example, may not stay in solution in the water. Once in Lake Ontario, the molecule can volatilize, in which case it may be carried by air currents to fall out in another lake or on land. Alternately, once in the water, the molecule may bind to a particle and settle to the bottom. Here it can stay and eventually be broken down by bacterial processes, or it can be ingested by bottom-dwelling organisms, in which case it can move up the food chain when these organisms are eaten. Even if the PCB molecule stays in the water column, it can enter plankton which are then consumed by pelagic or benthic organisms which are in turn consumed by forage fish. The forage fish may in turn be eaten by a herring gull, or by a large fish which may in turn be eaten by a Great Lakes angler.

Another biological transfer that has greatly increased in the last few years is transfer of materials including contaminants from the water column to bottom sediments by zebra mussels. The mussels produce prodigious quantities of pseudo-feces, undigested material which they filter from the water and release to bottom sediments. This has the potential for a major shift in not only energy transfers, but movement of contaminants as well. This may at least partially account for changes in contaminant trends being observed in fish.

Figure 4 provides a simplified schematic of contaminant cycling showing various pathways. It also illustrates why restoration strategies must be based on a knowledge of the ecosystem.

Fundamental questions remain about how contaminants move around the Great Lakes ecosystem. What are the total loadings of contaminants of concern? What is the net effect on the Lakes of atmospheric deposition and volatilization of contaminants? How can we effectively deal with long-range transport of contaminants from other countries and continents? What is the relative contribution of historical sources (such as releases from sediments) to levels found in water and fish? What is the effect of zebra mussels on contaminant cycling? Why are contaminant levels in biota no longer declining even though loadings of persistent toxic contaminants have been steadily reduced since the 1970s?

Clearly, the ecosystem responses to actions such as decreased loadings of contaminants are not simple. As an example, "turning off the tap" of PCBs from industrial discharges has not fully solved the problems of PCBs in fish: policymakers need to consider all sources, including bottom sediments and air, and need to consider the interactions among these sources. They must also recognize the response times involved once the "taps are turned off".

Zebra Mussel: Great Lakes Filter

In 1986, the zebra mussel arrived unannounced, discharged from the ballast water of a European ship. Its introduction into the Great Lakes set in motion a series of cascading events. With few natural predators, the imported bivalve proliferated rapidly. Concern in the early years coalesced around threats to infrastructure, especially clogging of water intake pipes, and the bottom fouling of ships and boats. However, recent studies indicate that impacts of the zebra mussel may go far beyond that of a nuisance. Some Great Lakes researchers believe that the zebra mussel has the potential to fundamentally alter aquatic

> **"... the zebra mussel may go far beyond that of a nuisance. Some Great Lakes researchers believe that the zebra mussel has the potential to fundamentally alter aquatic community structures."**

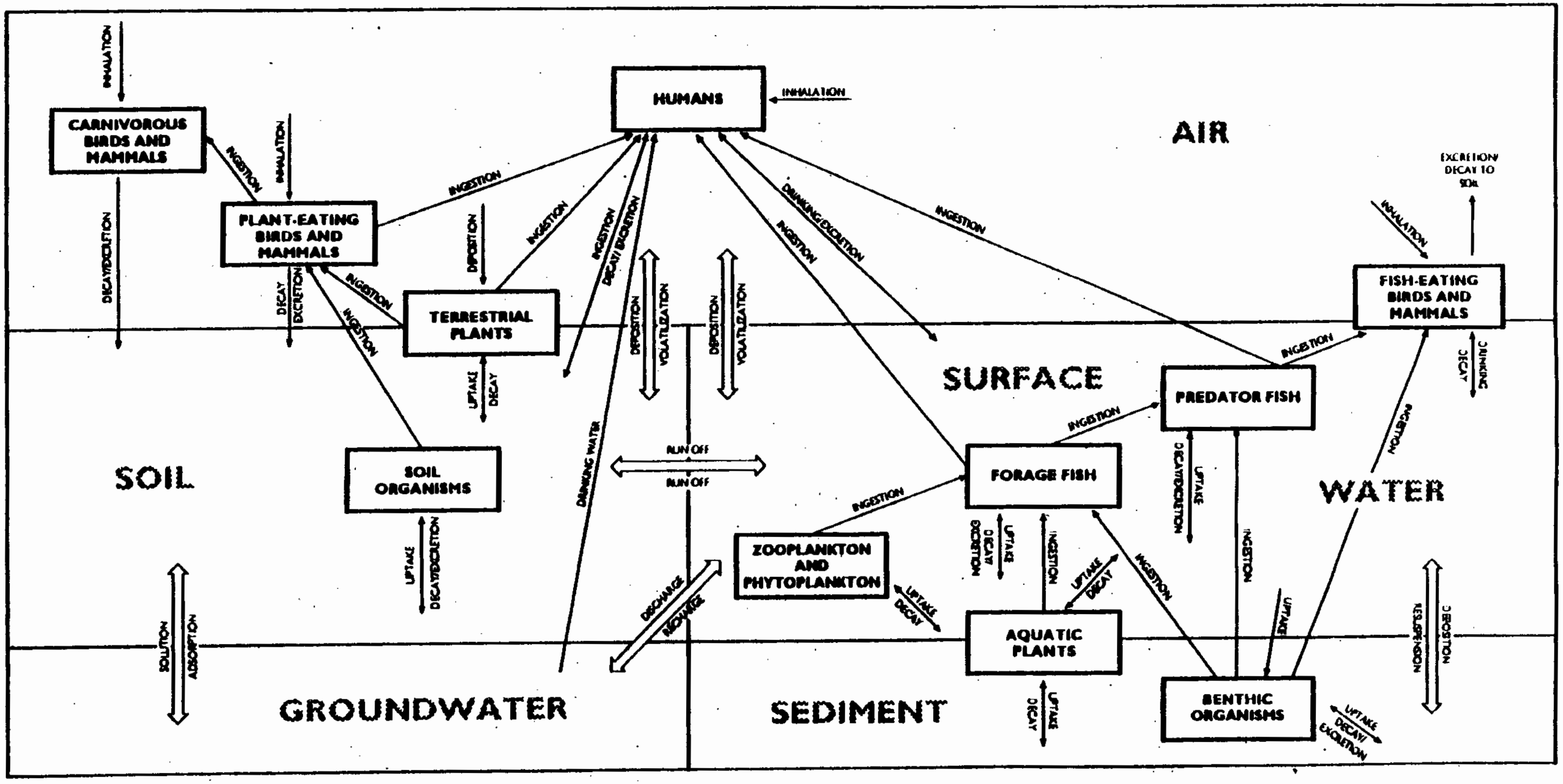


FIGURE 4: CONTAMINANT CYCLING IN THE GREAT LAKES ECOSYSTEM

community structures.

The half-inch long zebra mussel has a voracious appetite. It feeds on plankton and detritus that it filters from large volumes of water. In so doing, it transfers energy from the pelagic (open water) system to the benthic (bottom-dwelling) system. Zooplankton that otherwise would be available for forage fish, instead fuel a population explosion of zebra mussels. Increased water clarity has been observed across the basin as zooplankton and detritus are removed by mussels from the water column. In relatively shallow areas, this improved clarity has resulted in increased penetration of light and increased growth of submerged aquatic vegetation. This has likely increased spawning, nursery and forage areas for some fish species, while probably reducing them for others. Predation on fry can also increase due to increased clarity. As noted in Chapter 4.1, in Lake Erie, the impacts of zebra mussels on detritus and zooplankton have resulted in the severe impacts on native Unionidae clams, and may be contributing to declines in stocks of smelt, yellow and white perch.

Impacts of the Changing Nutrient Regime

The reduction in phosphorus loading achieved over the last 25 years has reduced the total quantity of algae in Great Lakes waters enough to meet the objectives set out in the GLWQA. This reduction of phosphorus to historical levels appears also to be having an impact on the abundance of plankton in the Great Lakes. Declines in levels of zooplankton have been noted in Lakes Ontario and Michigan. Zooplankton sustain forage fish such as alewife and smelt, which in turn sustain top predator fish.

Levels of top predator fish in the Great Lakes have been sustained at unnaturally high levels through the enhanced productivity of the system (high levels of phosphorus which supported very large populations of forage fish) and through stocking of indigenous and exotic species such as chinook salmon and rainbow trout. While this has contributed to the growth of an extensive sport fishing industry, it is not sustainable in a system in which nutrient levels are declining. From an ecological (and ecosystem management) point of view, expectations for fish yield (both commercial and sport) need to be adjusted to levels that are sustainable over the long term. This has implications for targets for stocking programs throughout the Basin, economic implications (from reduced yield) and poses potential conflicts with angler groups. A related issue is the question of what types of top predators should be stocked. Species such as chinook salmon, while they are desirable sport fish, are not established as naturally-breeding populations (except in some tributaries in Lakes Ontario and Superior); lake trout, one of the "natural" top predators in the Great Lakes, are not so popular with anglers.

A second set of scientific questions arises from the question of the impact of changing nutrient regime on community structure. If lowered phosphorus loadings are affecting community structure, are they also having an effect on contaminant cycling? At this point, the answer is not known.

Restoring Aquatic Systems

A recent report, *Great Lakes Environmental Assessment* (LTI, 1993), outlines starkly the current conditions of the Great Lakes fishery:

"Fish populations in the past were comprised only of native species which evolved together into a rich and diverse population that was self-regulating, productive, and comprised of many species representative of oligotrophic conditions. Fish communities in the Great Lakes today are of smaller mean size, composed principally of pelagic (open-water) species, and large benthic and predatory species that dominated early fish communities are severely diminished. Communities are now dominated by fecund (i.e. capable of rapid population growth), non-indigenous (i.e. exotic) species such as alewife and rainbow smelt. Numerous native species are now extinct or have been extirpated. Top predators are also exotics (Pacific salmon) or stocked hatchery-reared, genetically inferior lake trout and the sea lamprey...Current fish communities are unstable, are difficult to manage, require large amounts of public moneys to maintain some semblance of integrity, and are constantly changing in response to the various stresses that are imposed upon them."

There are many lessons to be learned from the past. One of these is that there is no quick fix to the ecological problems facing the fishery. Past management decisions — stocking of non-indigenous predators, alterations and destruction of habitat — were made without consideration of the impacts on the total aquatic system. Ecological systems are complex webs of interconnections, and seemingly innocent actions — building a dam here, introducing a sport fish there — have had profound and irreversible effects. Actions to restore the Great Lakes fisheries must proceed based on a firm understanding of the impacts of actions on aquatic birds, mammals, amphibians and reptiles, aquatic organisms at all trophic levels, and people.

5.0 MANAGEMENT CHALLENGES FOR THE FUTURE

As shown in Chapter 3, the health of the Great Lakes ecosystem is variable. In Lakes Huron and Superior which are less urbanized and industrialized, water quality, aquatic communities and habitats are relatively healthy; in the other lakes, human activities have caused widespread environmental degradation. Even in the other Lakes, though, progress has been made in halting or undoing the damage caused by past unsustainable practices: water is cleaner, fish and wildlife communities are healthier than they were twenty years ago, some progress has been made to protect and enhance aquatic habitat, and some indigenous top predators are undergoing a resurgence. Society is moving — many may argue, too slowly — to embrace the principles of sustainability, waste reduction, pollution prevention, and resource efficiency. Despite the progress that has been made in the last twenty years, much remains to be done. Persistent contaminants continue to cycle through the ecosystem affecting fish and wildlife, and the effects of long term exposure to small concentrations of contaminants continue to be discovered. Aquatic habitat loss has been slowed, but it continues to take place on a massive scale. Exotic species continue to destabilize aquatic communities, degrade habitat, and alter cycling of nutrients and contaminants. Individuals, municipalities, industries and farms still discharge pollutants into air, soil and water.

The complexity of the ecosystem and the intricacy of interrelationships pose tremendous challenges for managers in the 1990s. How well these, and other challenges are met will define the condition of the Great Lakes for future generations. Some of these challenges include:

"The complexity of the ecosystem and the intricacy of interrelationships pose tremendous challenges for managers in the 1990s. How well these, and other challenges are met will define the condition of the Great Lakes for future generations."

The challenge of adequate information: This report (and the Working Papers on which it is based) cite numerous examples of areas in which basic research and data collection needs to be done. Needs include basic economic data on the Great Lakes Basin, data on quality and quantity of aquatic habitat, information on contaminant cycling, a better understanding of food web dynamics, and spatial and temporal data on the health of humans and aquatic biota. Effective steps forward require good information on which to base decision-making, information on stresses, interactions and effects. It is vital to fill these priority data gaps.

The challenge of information management and communication: Information on environmental conditions is possessed by hundreds of boards, agencies, commissions, and interest groups in the Basin. But all too often this information is locked in filing cabinets, or sitting on shelves. Moving forward to restore ecosystem health will require taking advantages of the tremendous strides made in computer networks, integrated information, cable, and other telecommunication opportunities to improve communication on environmental issues.

The challenge of how decisions are made: Traditional decision-making is linear. A decision is made by an individual or agency, it is passed along for review or approval by a long "chain of command." This is time-consuming, compartmentalized, and antithetical to the ecosystem approach. The ecosystem approach requires "round table," interdisciplinary, inter-jurisdictional and intersectoral approaches to decision-making, approaches which aim for consensus among stakeholders.

The challenge of institutional arrangements: The goal of restoring and maintaining the integrity of the Great Lakes Basin ecosystem poses many challenges to institutional structures. It requires recognition of ecosystem impacts from all decisions: recognition of effects beyond the narrow purposes of specific laws, regulations or organizational missions. It also requires a consensual "buy in" to goals, objectives and strategies from federal, state, provincial, regional and municipal governments, and from the private and non-governmental sectors. Because of the complexity of the Great Lakes Basin ecosystem, and the complex nature of the problems it faces, partnerships and coordination of actions are key to implementing an ecosystem approach to management.

The challenge of sustainability: Restoration and protection of the Great Lakes ecosystem requires a commitment to achieving sustainability. As a society, we still deplete non-renewable resources, still spend our environmental "capital." A truly healthy Great Lakes ecosystem will be one in which the consideration of the environment and the economy will be integrated with the needs of humans in a balanced and sustainable manner.

The challenge of dealing with biodiversity: Recognition of the need to protect genetic resources and the habitats needed to sustain various species, genetic variety within populations, and biological communities poses new challenges that fit well within the ecosystem approach. Two of these challenges are whether programs can be adapted to supply the information needed to address the issue, and whether effective strategies to protect biodiversity can be developed.

The challenge of agreeing on endpoints for restoration: Since some of the genetic diversity and physical features of the system have been irrevocably lost, and some exotic species appear to be permanently established; how can physical, chemical and biological integrity be defined? What measurable conditions should programs seek to attain?

The challenge of dealing with a focus on places: Applying an ecosystem approach to restoring and maintaining the Great Lakes Basin ecosystem requires a recognition of the extent to which natural systems vary from place to place, and how local systems relate to those around them. Traditional environmental regulations and programs have used blanket objectives and standards, used on a national, provincial or state-wide basis. One of the challenges for governments and other stakeholders is to understand and address restoration with respect to local ecosystems (both structure and function) and their linkages elsewhere.

The challenge of connecting decisions with ecosystem results: A major part of the challenge is to understand ecosystem problems and the stresses that cause them. Another important aspect of the challenge is establishment of well defined ecosystem objectives and indicators to measure success in restoring and maintaining ecosystem integrity. Such indicators can provide a focus for bringing together seemingly disparate programs and serve as a basis for integrating programs that were originally created to deal with separate aspects of environmental quality, resource management or other purposes.

The challenge of subtle effects of toxic substances on people and wildlife: The subtle effects of long term exposure to small quantities of toxic substances poses a challenge to managers as well as to researchers. If some substances have effects at such low concentrations that the ecosystem has virtually no ability to absorb them, or the global environment already contains concentrations at levels that may be causing adverse effects, how can use or generation of them be avoided or prevented?

APPENDIX A 400 YEARS OF CHANGE

Physical Characteristics

To understand the Laurentian Great Lakes Basin ecosystem, one needs to understand the scale and unique characteristics of what the French missionary, Father Gabriel Sagard, dubbed the "Sweetwater Seas". The Great Lakes — the world's largest freshwater system — cover an area of 244,160 square kilometers [km] (94,278 square miles [m]). More than 80,000 smaller lakes and some 750,000 km (466,041 m) of tributaries lie within the Great Lakes Basin. It drains an area of 765,990 square km (295,772 square m), an area bigger than the State of Texas. Ontario and eight U.S. states lie completely or partially within the Basin (see Figure 1).

Because of their large surface area, the Great Lakes are vulnerable to atmospheric deposition of contaminants. In other words, they are a "sink" for airborne pollutants, some of which are transported from great distances outside the Basin. Also, and importantly, the Lakes are a source for some persistent toxic contaminants such as PCBs that volatilize from their surfaces (primarily during the summer months) into the air and cycle through the system.

Not only are the Great Lakes large in terms of surface area, they are also, (with the exception of Lake Erie) very deep (see Figure 1). These large, deep lakes contain a huge volume of water, less than 1% of which leaves the system annually through the bottleneck of the St. Lawrence River. Because the flushing time for the Lakes is so long — for example, some 191 years for Lake Superior — relatively small percentages of pollutants entering the Lakes are exported through their outflows. Contaminants can also accumulate in bottom sediments and in the food web.

History

In the year 1615, Samuel de Champlain first sighted the Great Lakes. What he and subsequent explorers discovered in the Basin was a complex, balanced and extremely diverse ecosystem. It was a land in which many of the landforms had been carved out or left behind in the wake of the retreating Wisconsin Glaciers. The retreating glaciers left behind a legacy of lakeplains, moraines, eskers, kettle lakes, inland wetlands, and extensive rivermouth estuaries. A wide variety of vegetation had adapted to the diverse landforms and moderate climate. In the cool, dry north, vast coniferous forests clung to the thin, acidic soils of the Boreal zone; in the wetter and warmer south, Carolinian hardwood forests grew on rich soils. Diverse wildlife communities had adapted to the vegetation and topography.

Population numbers remained low until European settlement started in earnest in the mid to late 1700s. The history of European settlement is directly linked to the area's principal geographic feature — the Great Lakes and their tributaries. In the absence of road networks, settlement of the Basin by Europeans and transportation of goods was dependent on transportation by water through lakes, rivers and linking canals. Major "gateway" cities in the region such as Montreal, Toronto, Buffalo, Cleveland, Detroit, Chicago, Milwaukee and Duluth all began as ports. Canal building was started early to improve links within and without the Basin; the Erie Canal link was made in 1826. Commercial fishing in the Lakes started in the early 1800s. The major settlement period of the Great Lakes coincided with the rapid development of industrial and transportation technologies: with abundant water resources, cheap hydroelectric power, productive agricultural land, access to raw materials and an available labor force, the region developed an unparalleled advantage in domestic and overseas markets. The presence of the Great Lakes encouraged the development of water-intensive industries and waterborne shipment of raw material and finished goods; later intensification saw the emergence of a complex of primary and secondary manufacturing.

Along with the economic growth came rapid changes in the natural environment. By the beginning of the 20th century, settlers had cleared huge tracts of forests in the Basin for agricultural purposes or for timber, forcing many species of wildlife to retreat. Dams built on rivers to provide power for milling grain and lumber were interfering with fish spawning, and the removal of trees and shrubs from streambanks was causing erosion and sedimentation. This also led to changes in the temperature regime of these rivers, contributing to the demise of cold-water species. In coastal cities, bulkheads and piers were built, nearshore areas and coastal marshes filled, and harbors and river mouths dredged. This habitat destruction, coupled with overfishing, was causing a decrease in fish populations. Additional stress on aquatic communities came later from exotic species such as alewife and sea lamprey that spread to Lake Erie and the Upper Lakes through canals. To support rapidly increasing populations, cities spread outwards, and houses were built on agricultural lands, forested areas, river valleys, and wetlands. Residents were dumping garbage and sewage into Lakes and rivers or onto land, and industries were discharging their wastes directly into the air or water.

By the beginning of the 20th century, there were many indications that water quality was deteriorating and the Great Lakes Basin ecosystem was out of balance. Public health concern over the incidence of water-borne diseases such as typhoid was such that in 1912 the Canadian and U.S. governments referred the issue of pollution of the Great Lakes to the International Joint Commission (IJC) for study. As a result of the Commission's work, governments began building water treatment and sewage treatment plants in urban centers. This usually included chlorinating the drinking water and sewage effluent. In the 82 years since that first referral, many Great Lakes environmental problems have come to light — problems including eutrophication, high coliform bacteria levels in recreational waters, impacts of persistent toxic contaminants on wildlife and fish, imbalances in aquatic communities, loss of habitat and many others. Governments have tackled these issues as they arose.

Stocking programs were introduced

in an attempt to re-establish native top predator fish such as walleye and lake trout. The walleye fishery in Lake Erie has rebounded because of strict harvest controls and a total fishing ban in the early 1970s and also because of phosphorus controls. Walleye populations are undergoing a resurgence in Lake Ontario and have stabilized in Lakes Huron and Superior. However, attempts to re-establish naturally-reproducing populations of lake trout have not been successful except in parts of Lakes Huron and Superior. Effective binational programs were set up to control populations of invading lamprey. As new threats emerged from such exotic species as zebra mussels, quagga mussels, and purple loosestrife, governments in the Great Lakes Basin began to develop strategies to control them.

The eutrophication of Lake Erie grabbed headlines and attention in the late 1960s and early 1970s and prompted the U.S. and Canadian governments to sign the Great Lakes Water Quality Agreement of 1972. Under this agreement, which focused on the eutrophication problem, the governments developed programs to reduce the loadings of phosphorus to the Lakes. As a result of joint actions, phosphorus loadings to all the Lakes have declined since 1976. Concentrations of phosphorus in open water have also declined, which has resulted in a noticeable reduction in the growth rate of algae, both offshore and in nearshore areas. Today, although eutrophication is still a localized problem in some Areas of Concern, it is no longer a problem in the open waters of the Great Lakes.

In 1978 the GLWQA was renegotiated by the Parties and its scope was broadened to include such issues as control of persistent toxic substances, non-point source pollution, and other matters. In 1987 the Agreement was expanded to include contaminated sediments, airborne contaminants, management plans and ecosystem indicators.

The Parties (and their provincial and state partners) have used a mix of strategies to tackle the problems of persistent toxic substances. Basin-wide monitoring and surveillance programs were developed to monitor contaminant levels in air, water, sediment, fish and wildlife. Regulatory programs continue to reduce discharges of pollutants. Demonstration programs are showing the feasibility of cleaning up contaminated sediments and of restoring and protecting habitat. Pollution prevention is increasingly being used to reduce use and discharge of contaminants.

Increasingly, ecosystem-oriented multimedia approaches are being developed. Under the GLWQA the Parties agreed to prepare ecosystem-based Remedial Action Plans in 43 Areas of Concern in the Great Lakes to address impaired uses. Under that agreement, the Parties are also developing Lakewide Management Plans to address lake-wide contaminant problems, and are expanding these to include other issues such as habitat.

Strategies to deal with environmental problems have changed in the last two decades. In terms of pollution control, governments are moving from a reliance on "react and cure" approaches to those that anticipate and prevent problems from occurring. As part of this shift, the

Parties agreed in 1990 to develop Pollution Prevention strategies for the Great Lakes to assist municipalities, industries and individuals reduce their loadings of persistent toxic substances. With respect to ecosystem impacts from physical and biological stresses, governments have been slower to respond. Habitat continues to be lost and exotic plant and animal species are having profound effects on the ecosystem, while most funds are spent on the control and clean up of persistent toxic substances.

NOTES

NOTES

NOTES

NOTES