STATE OF THE GREAT LAKES

1. INTRODUCTION

This report summarizes the state of the Great Lakes as observed at the end of 1994 by the governments of including genetic diversity that has evolved over thousands of years. This genetic legacy, consisting of evolving traits that survived during varied conditions over millennia, is the basis for the biodiversity of the ecosystem.

This report views the state of the Great Lakes ecosystem by looking at the living system, specifically the health of aquatic communities and humans. From that perspective it examines the major stresses which affect the health of the system. Detail is provided in the background papers to this report.

As discussed in this report, the state of human health within the Great Lakes basin is determined primarily by factors unrelated to conditions in the Lakes. The stresses related to the Lakes that can significantly affect human health are toxic contaminants from the consumption of fish, and microbial disease organisms encountered when swimming, or occasionally found in inadequately treated drinking water.

In contrast to human health, the health of aquatic organisms is primarily determined by the many interacting physical, chemical and biological factors within the Lakes. This is because most aquatic organisms obtain all of their food from within the system and are in continuous contact with it. Thus, aquatic community health is the direct result of the complex conditions and interrelationships within the Great Lakes ecosystem.

The Setting

By almost any standards, the Laurentian Great Lakes basin is rich in resources. The Great Lakes contain one-fifth of all the fresh surface water 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 33.2 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, and perhaps because of them, the Great Lakes basin ecosystem is under tremendous stress resulting from human improvement has been made in control of nuisance conditions, nutrients, human disease-causing organisms, and in conventional pollutants that lead to oxygen depletion (biochemical oxygen demand). Also, much progress has been made in controlling toxic contaminants, although much remains to be done. In contrast, although some progress is being made in protecting and restoring habitat, continuing losses far exceed gains. In the case of biological diversity, because each loss of genetic diversity is permanent, all losses are additive. Thus the challenge facing Great Lakes rehabilitation, is to minimize or eliminate the loss of native species and to protect the genetic variation within those species to the greatest extent possible.

The long term losses in biodiversity and in habitat have been severe as reported in the Aquatic Community Health and Aquatic Habitat and Wetlands background papers. Although increasing efforts are being made and losses in biodiversity and habitat are slowing, the low point has probably not yet been reached for both aquatic community health and habitat. 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 high priority species and the ecosystems necessary to support them.

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 water borne diseases. Now the risk of illness from pathogens is slight and acute risks from toxic substances have been virtually eliminated, although the chronic effects of long-term exposure to low levels is still uncertain.

2. CONCEPTS OF ECOSYSTEM HEALTH AND INTEGRITY

Concepts of human illness and wellness are fairly well defined and familiar to most people. Applying similar concepts to the entire ecosystem is possible, but not yet well defined, however, ecosystem health can be measured to some degree at various levels. For example: populations can be measured as to age, size, reproductive success, incidence of disease, and rate of death. Alternatively, health of individual organisms can be measured by biochemical, cellular, physiological or behavioural characteristics.

One expression of ecosystem health is that of ecosystem integrity, the term used in the Great Lakes Water Quality Agreement. The Agreement's stated purpose is “to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem”. While not precisely defined, integrity is unlj0.92044ral char56.0675 organize, and also the physical and chemical environment needed to support good health. This stands in contrast to the physical, chemical and biological stresses which act to disrupt integrity and are usually the result of human activity. Figure 2 illustrates these stresses and their relationship to the physical, chemical and biological environment.

An essential concept in dealing with ecosystem health is that ecosystems and ecological communities are dynamic and exist within ranges of condition that reflect the various disturbances that occur in nature even without human activities. They exist in balance with these disturbances and their composition changes through sequential states that tend toward stability and increasingly complex interrelationships. Mature and relatively stable communities tend to contain proportionately more organisms that are longer lived and have specialized and demanding habitat requirements. The Great Lakes ecosystem was in this state before the coming of European settlers.

3. INDICATORS

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. One way to determine the status of the health of the Great Lakes ecosystem is to use indicators, which address a spectrum of conditions ranging from the health of humans and other living components of the system to stressors and the activities that cause them. Ecosystem health indicators measure ecosystem quality or trends in quality that are useful to managers and scientists.

An illustration of one such spectrum can be found in Figure 3.

To determine whether conditions are getting better or worse it is necessary to identify things that people can measure and accept as indicative of the condition of the system. Further, if these indicators can be agreed upon as representing acceptable conditions, they can serve as objectives, targets or criteria to be achieved through protection or restoration of various attributes of the system.

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 background paper.

Ecosystems are inherently complex so that indicators cannot be completely representative of all possible conditions. A few very simplified indicators were developed for SOLEC by a team of technical experts and are shown in Table 2. There are many levels of increasing detail and specificity as subsets of these. The indicators developed are 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

been a succession of invasions and deliberate releases of exotic (non-indigenous) 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 and the following fish species: alewife; smelt; gizzard shad; white perch; carp; brown trout; chinook, coho and pink salmon; rainbow trout; and round goby. To this list can be added more recent imports such as the zebra and quagga mussels, and fish such as 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 the aquatic community in the Great Lakes.

Exotic species may impact native organisms in a variety of ways ranging from direct predation or competition for food, to disruption of food chains or habitat. Whatever the mechanism of impact, the continuing presence of these non-indigenous species poses substantial problems for the rehabilitation and maintenance of native species associations.

This loss of biodiversity and the 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, habitat loss, pollution and exotic species. Native top predators, once dominated by lake trout, have been replaced by hatchery-reared imports. Table 3 lists the many species of Great Lakes fish that have been extirpated or are severely depleted due to human activities. What is not shown by the table is the fundamental loss of genetic diversity among surviving species. U.S. and Canadian stocking programs to reintroduce lake trout and non-native salmonid predators to the Great Lakes, have resulted in the development of highly successful sports fisheries providing a wide range of species for anglers. However, they rely heavily on continued stocking and the stability of fish communities and fisheries are not predictable at this time.

Three indicators for measuring the health of aquatic communities were selected. The first indicator — the number of native species lost
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the birds were still being exposed to excessive amounts of PCBs and other organochlorines from the fish in these hot spots. 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 other areas of the Great Lakes.

The reproductive success of breeding eagles eating Great Lakes fish remains lower than that of those nesting inland. However, recovery of the bald eagle is likely to be limited by contaminants, by the absence of appropriate habitat, and may be limited by food supply. Over 80% of the Lake Erie shoreline, and substantial portions of the shorelines of Lakes Ontario, Michigan and Huron are no longer suitable habitat for the bald eagle because of agriculture, urban sprawl and other human disturbances (Figure 7).

Mink and otter have also shown the effects of exposure to contaminants. Both live in wetland habitat near the shorelines and consume Great Lakes fish in their diets. Mink diet consists mainly of other mammals but is supplemented by birds, fish and invertebrates. They are one of the most sensitive mammals to PCBs, resulting in reproductive problems and death. Otters may not be as sensitive to these chemicals, however they may be exposed to higher levels than mink because their diet consists mainly of fish. Trends in mink populations have followed those of fish-eating birds; the population began to decline in the mid 1950s and was lowest in the early 1970s but have recovered somewhat in the 1980s. Data for otter populations have not shown the same trends, however they do have a lower rate of reproduction and therefore, slower recovery. Mink and otter could serve as biological indicators of the levels of PCBs in the shoreline wetlands habitats of the Great Lakes basin. Thriving populations would indicate the “virtual elimination” of PCBs from their environment.

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.

Over all, the status of aquatic communities is assessed as mixed/improving. This is based on recovery resulting from pollution control since the 1970s.

4.2 MAJOR STRESSES ON AQUATIC COMMUNITIES

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

- exotic species, over-fishing and excess fish stocking (including non-indigenous species); resulting in imbalances in aquatic communities and loss of biodiversity;

- degradation and loss of tributary and near shore habitat including coastal wetlands;

- impacts of persistent toxic contaminants; and

- eutrophication in localized areas.

Exotic Species, Excessive Harvest 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. This has been discussed in the section on m basis for a significant proportion of the total biodiversity of the Great Lakes basin ecosystem. Among all types of aquatic habitats, the inshore zone (and its wetlands) ranks highest in terms of performing these functions (Figure 8 shows the distribution of U.S. Great Lakes coastal wetlands).

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 adequate spawning areas, for example, becomes less obvious at least in terms of fish production. In highly polluted areas of the Great Lakes, fish communities may have at least partially compensated for these effects by restructuring and replacing missing 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.

Stress on aquatic community health caused by loss and degradation of physical habitat is pervasive throughout the Great Lakes ecosystem, but is most notable in the near shore and wetland areas. These habitats exist in a relatively narrow band along the shores and it is these highly diverse and biologically complex areas that contain unique assemblages of organisms and provide food and shelter for many species during sensitive reproductive and juvenile stages. The highly productive shallow water habitats are particularly crucial to forage fish and wading birds.

In pelagic (deep water) areas the loss of habitat quality is not well documented, but sedimentation is probably impacting the benthic community and may be impairing some spawning areas. Anoxia in the hypolimnion (colder bottom layer) of the central basin of Lake Erie is still affecting the benthic community there, although nutrient control has reduced the area affected. For Lake Erie some anoxia may be a naturally occurring phenomenon. In shallower areas such as western Lake Erie and other near shore areas, the benthic (bottom dwellers) communities were severely impacted by pollutants and sedimentation. Most of these areas are showing signs of recovery.

In the shallow littoral zone, often characterized by the presence of rooted aquatic vegetation, aquatic communities have suffered large losses in area and in the quality of the areas that remain. Destruction and degradation of the nearshore habitat has been caused by a variety of factors, but primarily by draining, sedimentation, filling, and invasion by exotic species such as carp. Similarly in the tributaries and associated wetlands, aquatic communities have been degraded or lost due to those same stresses. Further loss of habitat has been caused not by actual destruction, but by isolation from lakes by dams and dykes. Lastly, degradation has occurred because of changes in timing and duration of inundation and drying because of changes in river flows and regulation of lake levels. These changes destroy aquatic communities that have evolved with cycles established over many centuries.

The quality of chemical habitat has been degraded first by oxygen depletion in harbours and then by excess nutrients and widespread eutrophication. This has been followed by contamination by bioaccumulative persistent toxic substances as well as by non-persistent toxic substances.

The first indicator selected for the state of aquatic habitat and wetlands is the loss of

North American Waterfowl Management Plan which has resulted in the protection of over 17,500 hectares of wetlands in the basin.

Persistent Toxic Substances

Persistent toxic contaminants have had an impact on fish and wildlife species in the basin as noted in the aquatic community health section. Observed effects include alteration of biochemical function, pathological abnormalities, tumours, and development and reproductive abnormalities. Recent studies have suggested that the estrogenic effects of some organochlorines are implicated in developmental abnormalities in wildlife species. A possible consequence of the 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.

first began on Lakes Erie and Ontario in the early 1970s and in 1975 for Lakes Superior and Huron by the Canadian Wildlife Service (CWS). Depressed productivity levels of herring gulls have not been found at most of the sites on Lakes Huron and Superior since 1975. However, on the more populated and contaminated lakes, reproductive success was low in the early 1970s and has improved since. From 1974 onward, organochlorine residues in herring gull eggs have generally declined from higher levels in the early 1970s (Figure 11).

Chemical residues in herring gull eggs have been monitored since 1974. Organochlorines, including PCBs, DDT/DDE, mirex, dieldrin and HCB, have shown a statistically 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.

Over all, contaminant levels have shown good response to control programs although the rate of response has slowed. However, it is important to recognize that although large percentage reductions have been achieved in comparison to peak levels, for many contaminants, an additional ten fold reduction is 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.

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 significant impact on aquatic communities. This is particularly of concern in tributaries, bays, coastal marshes and inland wetlands. Nutrient enrichment causes excess grow.0008r5 0 Td(i)Tj-0s lo5 level of chlorophyll a found today is consistent with the GLWQA objective for these Lakes of "reduction in the present level of algal biomass to a level below that of a nuisance condition". However eutrophication and/or undesirable algae continue to present problems in 21 of the 42 Areas of Concern (AOCs).

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 related to the continuing release of phosphorus from old bottom sediments, or, it may be that intermittent anoxia is an inherent property of Lake Erie's central basin.

Another nutrient that is monitored in the Great Lakes is nitrate-plus-nitrite. Levels have been increasing over the past two decades, especially in Lake Ontario (Figure 13). Major sources of nitrogen to the Lakes include agricultural runnoff, municipal sewage treatment plants and atmospheric deposition. The concentrations currently found in open lake waters do not create a public health concern because they are at least 20 times lower that the guideline for drinking water (10mg/L), however, monitoring will continue as warranted.

5. HUMAN HEALTH AND WELLBEING

The overall rating for environmental contaminant stresses from the Great Lakes on human health in the basin is mixed/improving. Because limited data exist to measure impacts of contaminant stresses on humans in the Great Lakes over time, the levels of contaminants in the ambient environment and in fish and wildlife are used as a surrogate. Based on this, the stress from toxic contaminants on human health was rated as 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 Great Lakes contaminants is through fish consumption.

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. Although basin-wide data for these measures are not available at this time, the 1994 Report Progress in Great Lakes Remedial Action Plans: Implementing the Ecosystem Approach in Great Lakes Areas of Concern did show 35 of the 42 AOCs around the Great Lakes hav2.2879 0 -13.2-16decliefBT/TT0 v.-0.0004 s-1.61

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consumption, particularly consumption of contaminated fish. Food is believed to contribute between 40 to nearly 100% of total intake 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 (skin) exposure. For contaminants other than chemicals, 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*. Its presence in drinking water caused over one hundred fatalities and 400,000 people to become ill in the Milwaukee area in 1993.

Human populations in the Great Lakes basin, as with 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. Figure 14 shows trends of PCBs and DDT in breast milk. Other contaminants include radioactive elements such as radon and air contaminants such as ground level ozone and smog.

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 is the 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 hospital for 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.

In the past, health researchers and public policy-makers 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, 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 "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 and then to be tested through appropriate long-term medical and scientific studies.

The health of the human population of the basin has improved dramatically since the portion of the inland area of the North

population of the Great Lakes basin grew by less than 1%. Ontario, with more than a third of Canada's population, has been gaining population nearly twice as fast as the Great Lakes states but its rate of growth is also slowing. By 1990, the Great Lakes states' population increased by only 1.7% since 1970 whereas Ontario's 1991 population increased by 31% from 1971. However, within this relatively static picture, substantial redistribution of population is taking place causing significant impact on the ecosystem. While both central city and rural areas have been losing population, suburban areas have been growing rapidly, often drawn to "coastal amenities" along the shores of the Lakes. Industry and service business development have been decentralizing from built-up city locales to suburban-exurban fringe areas and connecting corridors between metropolitan areas. Land and water availability, lower wage scales, transportation access, proximity to new residential markets and other cost/service factors are propelling this kind of sprawl.

The most significant population and related development issue in the Great Lakes basin and surrounding region is the continuing growth of major metropolitan areas and the virtually uncontrolled sprawl of lower density residential and other development. The detrimental consequences of these trends are well known. Increased generation of water and air pollution, higher transportation and residential energy use, increasing encroachment on agricultural lands and natural areas, higher housing costs, disinvestment in older communities and social disruption and burdensome infrastructure requirements portend a more difficult, if not unsustainable, future for the Great Lakes basin ecosystem. However, the escalating cost of extending utilities and other basic urban services to these lower density regions may ultimately slow the process and stimulate a more sustainable pattern. One of the challenges in attaining more sustainable forms of development is the lack of accurate and visible cost accounting showing the real cost to society of allowing suburban sprawl. A new land stewardship ethic would rely more on intensification of development within prescr[illegible]

On a positive note, the Great Lakes basin, with more than 260,000 square kilometres (100,000 square miles) of navigable water and 16,926 kilometres (10,579 miles) of shoreline, anchors an important and growing coastal recreation industry. The recreational boating industry is represented by boat manufacturers and retailers, marina operators, marine business suppliers as well as millions of recreational boaters and anglers. For the Great Lakes it is estimat [illegible] basin grew by 140%; that for 1980 to 1990 grew at only 83%.

Four other 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.

7. LAKE BY LAKE

Because of the large size of the watershed, physical characteristics such as climate, soils and topography vary across the basin. To the north the climate is cold and the terrain is dominated by a granite bedrock known as the Canadian (or Laurentian) Shield consisting of Precambrian rocks under a generally thin layer of acidic soils. Conifers dominate the northern forests.

In the southern areas of the basin the climate is significantly warmer. The soils are deeper with layers or mixtures of clays, silts, sands, gravels and boulders deposited as glacial drift or as glacial lake and river sediments. The lands are usually fertile and the relatively flat landscape has been extensively drained for agriculture. The original deciduous forests have given way to agriculture and sprawling urban development. Although part of a single system, each lake is different.

While it is recognized that all aspects of the ecosystem are interrelated, the agencies responsible for management have tended to set priorities for action because they can not adequately deal with all the environmental issues in their jurisdiction. In addition, the number of jurisdictions and agencies involved in management of the Great Lakes is quite large - two federal, one provincial and eight state governments, as well as thousands of local governments and various stakeholder groups - making the task of managing the Great Lakes ecosystem as a whole a major challenge. Also the management agencies and other stakeholders such as the scientists, general public, and industries do not always agree on the desired ecosystem goals and objectives for each lake.

The GLWQA addresses many of these problems. Canada and the United States are committed to the development and implementation of Lakewide Management Plans (LaMPs) for all of the Great Lakes. The LaMPs are designed to reduce loadings of critical pollutants so that the beneficial uses can be restored (see Table

have severe impact on perch and other native species. On the other hand, sea lamprey invaded the Great Lakes system in the 1800s, probably via the Erie barge canal. With the opening of the Welland Canal, and later the Sault locks, the lamprey gained access to all five Lakes. With no natural predators, the lamprey devastated the lake trout populations in Lakes Ontario, Erie, Michigan and to some extent Huron. Some stocks were lost in Lake Superior, but sea lamprey control, started in 1958, managed to halt the loss. The sea lamprey control program has resulted in a 90% reduction in lamprey abundance in Lake Superior. Without continued lamprey control, it is unlikely that lake trout populations could be sustained.

Chemical stressors of concern are bioaccumulative persistent toxic substances. Although Lake Superior receives proportionately little input of contaminants in comparison to its volume, they remain available to the food chain for a relatively long time. This is because there is little algae or suspended particles to absorb them and carry them to the bottom. There are nine chemicals of concern, as outlined in the Lake Superior Binational Program including mercury, DDT, PCBs and toxaphene-like substances. Toxaphene remains in the aquatic environment for a very long time and is mainly a problem in Lake Superior as well as northern Lake Michigan. Although data on toxaphene are complicated by analytical limitations, it appears that concentrations are showing little response to cancellation of its use as an insecticide. It is present in some Lake Superior fish at levels that require fish consumption advisories.

The largest external source of contaminants to Lake Superior is the atmosphere, via wet and dry deposition. This is the most difficult source to control since the contaminants may travel hundreds or even thousands of miles, and may undergo many chemical transformations, before being deposited on the Lake. Atmospheric deposition accounts for approximately 90% of some toxic contaminants input into Lake Superior. For semi-volatile compounds such as PCBs, however, outputs to the atmosphere can be a substantial fraction of total inputs (see Figure 18). Nitrogen is being monitored in the Lake with trends showing that it is increasing, although these increases have no apparent effect on the ecosystem. Input of nitrogen to the Lake from the atmosphere is suspected of being the major cause of nitrogen increases in the Lake. An estimated 58% of the total nitrogen load to the Lake is attributable to precipitation.

The trends in contaminant concentrations in fish can be seen in Figure 10. For PCBs, concentrations in lake trout declined significantly during the period 1977-1990 in Lake Superior as in the other Great Lakes. However, as in the other Lakes, the declines have not continued in recent years as can be seen in Figures 10 and 11. Whether this is the result of continuing sources, recycling of previous discharges or changes in the food chain remains to be seen.

Fish consumption advisories are in effect for many Lake Superior fish because of contaminants. Advisories are issued by mills. The more temperate southern basin designated as "early mortality syndrome". Treating the eggs in the hatchery with thiamine reverses the syndrome, but the ecological cause of the syndrome remains unknown. The goal of self sustaining lake trout populations based on natural reproduction remains elusive, but whitefish and bloater populations have increased and support a valuable commercial fishery. Habitat losses, especially wetlands, have been extensive throughout the basin, but have been most severe in the southern portion. Losses in habitat and biodiversity continue to add up as major stressors continue unabated. Urban sprawl and recreational development continue to destroy habitat and biodiversity as they do throughout the Great Lakes basin. Progress is being made in inventorying existing resources, but losses far exceed conservation and restoration efforts.

Accelerated eutrophication has been brought under control except in localized areas, and in Green Bay where good progress has been made, but much remains to be done. In Green Bay seven of the 12 impaired uses are the result of excessive nutrients. This case is a good example of problems caused by nutrients and how it has become recognized that land runoff must be addressed on a watershed basis if these problems are to be solved.

Trends for bioaccumulative persistent contaminants are similar to the other Lakes as described in section 4.2. Contaminants in fish in Lake Michigan are among the highest in the Great Lakes, being similar to levels in Lake Ontario (see Figure 10).

Fish consumption advisories are in effect for lake trout, brown trout, steelhead, coho salmon, chinook salmon, whitefish, walleyed pike, perch and smelt. It is advised that large lake trout and brown trout should not be eaten at all, whereas it is recommended that consumption of the others be in limited amounts. Advisory recommendations for frequency of consumption differ by species, size and location, so it is important for consumers to consult consumption guides in their respective jurisdictions.

On a lakewide scale contaminants are being addressed by both the Lakewide Management Plan (LaMP) and the Lake Michigan Mass Balance Study. A draft LaMP for critical pollutants for Lake Michigan was published early in 1995. The LaMP reviews contaminants, their effects and their loadings, and also incorporates five ecosystem objectives derived from the Lake Ontario LaMP. Following public comment and appropriate revision the plan will be adopted. Although the plan is primarily focused on toxic contaminants, work is currently underway to develop an expanded plan which will include natural resource and habitat factors as well as
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contaminants move into and through the Lake ecosystem. A mathematical model of Lake Michigan is to be constructed based upon intensive sampling. Sampling includes inputs from tributaries and airborne deposition, sediment burial and resuspension, and movement of contaminants through foodchains (Figure 19). The purpose is to better predict the benefits of reducing contaminant loads in terms of resulting decreases in contaminant levels in fish. The multi-year study will support improved management of contaminants throughout the Lake Michigan basin.

Fish community objectives for Lake Michigan were approved in 1995 in response to the Strategic Great Lakes Fisheries Management Plan and are to be factored into the LaMP.

7.3 LAKE HURON

Lake Huron, including Georgian Bay, is the second largest in area. It is the third largest freshwater lake in the world in area and sixth in volume. The population is approximately 2.4 million with about 55% of the population in the U.S. Like Lake Michigan, the northern portion is lightly populated and extensively forested. In contrast, the Saginaw River basin is intensively farmed and contains the Flint and Saginaw-Bay City metropolitan areas. Saginaw Bay, like Green Bay in Lake Michigan, contains a very productive fishery.

resting and feeding areas for migratory waterfowl. Some of the important staging areas on Lake Huron for migrating birds include the wetlands of Saginaw Bay, Severn Sound and the St. Marys River. Physical habitat loss in the past, in southern Lake Huron, was catastrophic as land was converted to agriculture and streams were dammed for various purposes.

With respect to stressors affecting Lake Huron, exotic species such as sea lamprey, zebra mussels, and purple loosestrife and other organisms pose major threats. Shortly after its arrival in the Lakes, the sea lamprey population exploded and nearly eliminated native fisheries by the 1950s and 1960s. In the late 1950s Canada and the U.S., under the auspices of the Great Lakes Fishery Commission, began treating tributaries and coastal waters with TFM, a chemical used to kill lamprey larvae in streams. By the 1970s the lamprey population had been reduced by 90% throughout the Great Lakes. However, lamprey are a growing threat in Lake Huron with populations doubling in northern Lake Huron since 1985. Using current methodologies, the population reproducing in the St. Marys River cannot be treated because of the large flow in the River and the many bays and side channels. Since salmon transport lamprey throughout the Lake, the problem will likely spread.

As shown in Figure 20 lamprey control is vital and should continue as a priority before the fisheries in Lake Huron are lost. More information is needed on the distribution of adult and larval lamprey as part of the search for non-chemical controls. Development of non-chemical controls are needed not only for the St. Marys River, but to allow reduced use of chemical treatment which has some undesireable side-effects. Efforts to deal with the problem are being coordinated by the Great Lakes Fishery Commission but costs may increase substantially. Invasion by zebra mussels has yet to run its full course and little can be done except to monitor its progress and try to understand the cause and effect relationships involved. The full impact on the food chain, aquatic community and biodiversity remains to be seen.

Contaminant levels in Lake Huron fish and birds are declining as they are in the other Lakes as seen in Figures 10 and 11. Continuing sources of contaminants are primarily from sediments from earlier discharges, airborne deposition and land runoff.

Shoreline development is a growing stress on habitat and aquatic communities as marshes and other wetlands are dredged, drained or filled, often for recreational development, including summer homes and cottages. Although the change is taking place in small increments, the collective effect is substantial. The most intense areas of impact are the result of urban population pressures from both Detroit and Toronto.

An emerging issue is how public and private natural resource lands within the basin are managed. Often land is managed by individual agencies or organizations carrying out single, often narrow, mandates. The efforts to maximize a narrow objective can have major negative impacts on the aquatic community as a whole or on components within it.

There is a danger of complacency for Lake Huron. As the “lake-in-the-mi

mussel invasion have become far more complex than the physical problems of clogging

Action Plans for the AOCs in the Lake Erie drainage basin, as well as coordinating with programs downstream such as the Niagara River Toxic Management Plan and the Lake Ontario LaMP.

Lake St. Clair

Lake St. Clair is a relatively small shallow lake of 1114 square kilometres (430 square miles) and a volume of 4.2 cubic kilometres (1 cubic mile). It lies between Lakes Huron and Erie but is completely within the Lake Erie drainage basin. There is a high population and industrial base surrounding it. This has led to the loss of much of the surrounding habitat/wetlands, and to contaminant problems in both the water and the sediments. Lake St. Clair and the St. Clair River are very important staging areas for migrating birds and fish, so habitat loss is a real concern. Zebra mussels are having a major impact on the Lake St. Clair ecosystem but the end result remains unknown. One effect of the mussels has been improved water clarity. This in turn has altered the nutrient cycling and food chains, as well as allowing aquatic vegetation to spread throughout the Lake. The vegetation provides improved habitat, but impedes some recreational uses.

As mentioned previously, there are four AOCs in the Lake St. Clair area which affect Lake Erie: St. Clair, Clinton, Detroit, and Rouge River. There is no specific LaMP for the Lake although it will receive some consideration as part of the Lake Erie LaMP. Fish community objectives have been developed for Lake St. Clair.

7.5 LAKE ONTARIO

Lake Ontario, although slightly smaller in area, is much deeper than its upstream neighbour, Lake Erie, with an average depth of 86 metres (283 feet) and a retention time of about six years. In terms of world rank of freshwater lakes, Lake Ontario is 13th in area and 11th in volume. Major urban industrial centres, such as Hamilton, Toronto and Rochester are located on its shore. The U.S. shore is less urbanized and is not intensively farmed, except for a narrow coastal plane.

There are approximately 6.6 million people living within the Lake Ontario basin of which nearly 69% reside in Canada. Most of the population is concentrated in the western half of the basin, including the Toronto-Hamilton crescent, that contains more than half of the entire Canadian Great Lakes basin population. U.S. population is concentrated in the Rochester and Syracuse-Oswego areas. Lake Ontario is also directly impacted by the Buffalo-Niagara area since pollutant loadings from that area typically flow into Lake Ontario via the Niagara River, rather than mixing into Lake Erie.

The aquatic community of Lake Ontario as in the other Lakes, suffered major losses because of agriculture, deforestation, damming of streams and urbanization. Atlantic salmon was extirpated through over-fishing and sedimentation of spawning habitat.

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Lake Ontario contains seven AOCs (Table 11), of which Toronto and Hamilton Harbour are the largest. The others are Port Hope and the Bay of Quinte in Ontario and Eighteen Mile Creek, Rochester and Oswego in New York. An eighth, the Niagara River AOC, supplies approximately 70% of the toxic contaminant loading to Lake Ontario. Lake Erie's Buffalo River also primarily impacts Lake Ontario rather than Lake Erie.

Lakewide, accelerated eutrophication has been brought under control, but remains a problem in localized bays and river mouth areas, notably Hamilton Harbour and the Bay of Quinte.

Contaminant levels in fish are following trends similar to the other Lakes as described in section 4.2 (and shown in Figure 10) but are relatively high and similar to those in Lake Michigan. The levels of contaminants are being maintained by the continued inputs from point and non-point sources, from atmospheric deposition and locally from the sediments. Levels declined se in La31 Tw -10.e8i0.505 0 Tine672 Tw -13(area-1.216 Td(levels)197 million fish were stocked in 1994). The province of Ontario has also encouraged increased harvesting of salmon and trout to reduce the demand for food by predator fish. There is still the question of rehabilitating the Lake Ontario fishery to a more "natural" system with, for example, a top predator species such as Atlantic salmon. Since Atlantic salmon depend on tributaries for spawning, they would also be a good indicator of Lake Ontario ecosystem health. However, much of the Atlantic salmon habitat has been destroyed through deforestation, stream modification, dams and pH changes. These factors were largely responsible for the demise of the Atlantic salmon in the late 1800s. It would take more than merely stocking the fish to

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component of the overall suite of environmental objectives for the LaMP.

7.6 THE CONNECTING CHANNELS

Connecting channels are often the most heavily utilized by humans, therefore all five of the connecting channels have impaired habitat. Part or all of each connecting channel has been designated as an AOC (as discussed in each lake section and shown in Table 12). In addition to the impacts of agriculture, industry and urbanization (which also affect the Lakes), the connecting channels suffer from physical alterations for shipping, water level management and power generation causing a loss of wetlands and rapids habitat.

8. MANAGEMENT CHALLENGES FOR THE FUTURE

As discussed in this report, 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 more disturbed Lakes, though, progress has been made in halting or undoing the damage caused by past unsustainable practices. The water is cleaner; loadings and levels of persistent toxic chemicals have been reduced from the those seen in the 1970s, and the nutrient control programs instituted in the 1970s have largely achieved their objectives. Phosphorus loadings are much reduced and nuisance blooms of algae are no longer a problem. In fact, success in reducing phosphorus loadings under the GLWQA has provided a binational resource management model to the world. Awareness of the fragility of the ecosystem is now widespread throughout the basin. Fish and wildlife communities are healthier than they were twenty years ago with some native (indigenous) top predators undergoing a resurgence, and some progress being made to protect and enhance aquatic habitat. Citizens have been galvanized into action over the past 20 years, and action at state/provincial and local levels to conserve and restore important ecosystems is now occurring through the RAP process and other domestic initiatives.

It must be recognized that there is still a long way to go to restore the Lakes to a healthy state, despite the progress that has been made in the last twenty years. Society is moving — many may argue, too slowly — to embrace the principles of sustainability, waste reduction, pollution prevention, and resource efficiency. However, the Lakes are besieged with pollutants released hundreds, or even thousands, of miles away from the basin, and locally pollutants are still being discharged into air, soil and water by individuals, municipalities, industries and agriculture. 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 an unacceptable scale. Exotic species continue to destabilize aquatic communities, degrade habitat, and alter the cycling of nutrients and contaminants.

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 which are not necessarily those that are best for the ecosystem. The emphasis for management of the Great Lakes has gradually shifted from traditional approaches to pollution control in a single medium, such as air, water or sediments, towards an ecosystem approach where agencies examine the combined impacts of a variety of stressors on the environment. This requires recognition of ecosystem impacts from all decisions and 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 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 and requires different perspectives that fit well within the ecosystem approach. Related 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. As discussed in this report some of the greatest stresses on biodiversity result from habitat destruction, over-exploitation of resources, and competition from non-native species.

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? Objectives for restoration of the physical, chemical, and biological integrity of the ecosystems of the Great Lakes are just now being developed. However, the historical benchmark (ie. the post-glacial state of the Great Lakes ecosystem) remains an important reference point with which to judge the extent of degradation of Great Lakes ecosystems and the prospects for various levels of restoration.

Jurisdictions around the Great Lakes are now faced with decisions regarding the restoration of the aquatic communities in the Lakes, and the composition of those restored communities. Justification of preferences for a particular community structure may be aided by historical analysis, but an alternate structure, with non-historical species performing the same ecological function, is also possible. One expression of this is to manage towards pre-settlement conditions, recognizing that these conditions will never be fully attained. The decision about which ecological community becomes the objective of restoration efforts is a matter of social