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 the United States and Canada as Parties to the Great Lakes Water Quality Agreement (GLWQA). Much of the material in this report, and its six background papers, was presented and discussed extensively at a binational conference, the State of the Lakes Ecosystem Conference (SOLEC), held in October, 1994. For that conference, working papers were prepared on six topic areas: aquatic community health, human health, habitat, contaminants, nutrients and the economy. These conference working papers have been finalized, and are the background papers to this report. Additionally, information obtained from the discussion sessions at the conference has been incorporated into this report.

It should be recognized that this report addresses the state of the Lakes, not the state of programs created to deal with stresses impacting the system. Program information is presented in a different series of reports prepared by the Parties individually, for example the Canada-Ontario Reports and the U.S. Reports to Congress on the Great Lakes. In presenting the State of the Great Lakes Report, the Parties wish to draw attention to the substantial improvements that have occurred in response to cleanup activities and to the major improvements yet to be achieved.

In developing SOLEC and this report, the Parties asked some basic questions that are often asked by decision makers and the average citizen:

Can we swim, eat the fish that we catch, and drink the water?

Are the Lakes affecting human health?

Are the Lakes getting better?

Are the fish and birds healthy?

How are endangered species doing?

What are we doing about exotic (non-native) species?

This report attempts to answer these and related questions by looking at the state of the Great Lakes ecosystem and the complex interactions with the many stressors on the system.

The ecosystem includes the interacting components of air, land, water and living organisms, including humans. The Great Lakes basin ecosystem is made up of a mosaic of smaller ecosystems each of which differs from the others, but none of which is separate from the others. They contain interacting physical, chemical and biological components. Each of these provides habitat for various living organisms. Within the living organisms are the genetic resources of the ecosystem, 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 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 become out of balance.

As European settlement began 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.

Through the efforts of government and citizens over the past 25 years, recovery has been made in many areas. Vast 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 understood to include the health of the constituent populations of the ecosystem, the biological diversity of the ecological communities, and the ecosystem’s ability to withstand stress or adapt to it.

Ecosystem integrity includes the health of living things, the ability of systems to selforganize, 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 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 also important to recognize that the economy also provides the means to control stresses and restore the system. The indicators developed for SOLEC and used here are rated based on information collected for the background 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).

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? 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. An illustration of the stressor-effects framework is provided in Figure 2.

4. AQUATIC COMMUNITY HEALTH

4.1 STATE OF AQUATIC COMMUNITY HEALTH

Compared to their chemical, physical and biological integrity 400 years ago, the Great Lakes have changed drastically. The devastating loss of biological diversity and subsequent establishment of non-indigenous (exotic) populations is the most striking indication of degradation of the Great Lakes. At least 17 historically important fish species have become depleted or have been extirpated (eliminated) from one or more of the Lakes. Amplifying this loss of species diversity is the loss of genetic diversity of surviving species. For example, prior to 1950, Canadian waters of Lake Superior supported about 200 distinct stocks of lake trout, including some 20 river spawning stocks. Many of these stocks are now extinct, including all of the river spawners. The loss of genetic diversity of lake trout from the other Lakes is even more alarming, with complete extinction of native stocks of lake trout from Lakes Michigan, Erie and Ontario and all but one or two remnant stocks in Lake Huron. Lake trout from other sources are being stocked into those lakes but little natural reproduction is ocurring.

Contributing to this loss of diversity has 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 — 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 because of 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 partially successful. One must bear in mind that even though species may be reintroduced, hatchery reared fish do not have the genetic variability of wild populations.

The second indicator, the Lake Trout Dichotomous Key, provides a measure of how balanced the aquatic ecosystem is. The Key is a complex index based on the scores from a series of questions relating to lake trout and the conditions necessary to sustain naturally reproducing populations. Because of the dichotomous structure (yes/no), the key does not necessarily reflect small changes or trends. The rationale for using lake trout as an indicator for ecosystem health is based upon their historical dominance in the Great Lakes food web and their biological characteristics — this makes them a good surrogate indicator of changes in aquatic ecosystem health. Further discussion on this indicator can be found in the Aquatic Community Health background paper.

Using this indicator, Lake Superior rated as good/restored, Lake Huron as mixed/improving, and Lakes Michigan, and Ontario as poor (Figure 4). For Lake Erie, the key applies only to the eastern basin of the Lake which is deep and cool enough to support lake trout. A similar key based on sustainable reproduction of the top predator fish in the remainder of the lake (walleye) would rate a higher score. While aquatic communities in all the Lakes have been significantly disturbed and altered by over-fishing, exotic species, habitat destruction, nutrient enrichment and persistent toxic substances, those in Lakes Michigan and Ontario are the most unstable.

The third indicator for the state of aquatic communities is reproductive impairment. This indicator is rated as mixed/improving in all the Lakes. Exposure to a variety of environmental stresses including organochlorine compounds (some widespread, some local) caused reproductive problems for Great Lakes wildlife, especially aquatic birds. In fact, 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), a reptile (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 tern). All of these, except the ring-billed gull, have shown historical evidence of reproductive impairment due to contaminants. In the 1950s, 1960s and early 1970s severe effects were observed and populations of some aquatic bird species declined, often because of thinning of egg shells. Population problems were often attributable to environmental contaminants, but in a few cases populations actually increased during times of high contaminant loadings, for example the population of ring-billed gulls increased during this time.

With the reduction in loadings of persistent toxic contaminants such as PCBs, most of the fish-eating bird populations have recovered and populations of herring gulls, Caspian terns, black-crowned night herons and double-crested cormorants have become re-established in the Great Lakes (see Figure 5 for cormorant populations). However, problems such as birth defects or failure to reproduce have continued to occur in a small percentage of the population in local areas. For example low rates of bill defects and other developmental abnormalities were seen through the 1980s in cormorant populations in areas of high contamination (toxic “hot spots” — see Figure 6). This suggests that 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 aquatic community health.

Degradation and Loss of Aquatic Habitat and Wetlands

The degradation and loss of habitat is a major stress upon aquatic communities. Habitat in general constitutes the entire ambient environment, including physical, chemical and biological aspects as illustrated in Figure 2. Upland habitat is of concern as it impacts the aquatic ecosystem and is addressed from that perspective.

Wetlands, tributaries, connecting channels, open lakes and near shore 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. The habitat that is important to any one species is the portion of the environment that significantly affects its survival during each of its life stages. For purposes of this report, emphasis is on aquatic habitat directly associated with the Great Lakes.

Basin-wide data on the quality and quantity of aquatic habitats are scarce and fragmented, however the best information exists for wetlands. A U.S. National Wetlands Inventory is now being developed which is mapping wetlands survey information, 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. 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 terrestrial, aquatic and avian species, providing areas for spawning, nesting, rearing, foraging and sheltering. Aquatic habitats, and the species that live within them, provide the 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 habitat (both in terms of quality and quantity), and 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 tributaries to 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.

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 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. Laboratory studies and field observations suggest that tumours 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 4. To measure the impact of persistent toxic contaminant stressors, 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. 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 declining contaminant concentrations in waters, sediments, fish and wildlife as illustrated in Figures 9, 10 and 11.

Levels of organochlorine contaminants in the tissues of top predator and forage fish declined significantly from the late 1970s to mid 1980s but have shown a slower rate of decline more recently (Figure 10). Despite this overall trend, during the late 1980s, in some areas, 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. Regardless of the general downward trend, levels of persistent toxic contaminants in certain 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 that varies in availability and contaminant content. As a result, changes in contaminant levels in fish may be influenced by shifts in feeding behaviour by the fish or elsewhere in the food web.

Adult herring gulls, as permanent residents of the Great Lakes basin, offer a monitoring opportunity to detect regional variability in contaminant stress that is not complicated by migratory patterns characteristic of other fish-eating bird species. Monitoring of reproductive successes at various sites 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 growth of algae, the decomposition of which depletes the oxygen needed to sustain other forms of aquatic life. Algae can also limit penetration of sunlight to the extent that rooted plants are affected.

Four indicators were used to measure nutrient stresses. Three were rated as good/restored. The first indicator is total phosphorus loadings, where GLWQA targets have been achieved in Lakes Superior, Huron and Michigan, with Lakes Erie and Ontario at or near their target loads. The second indicator is total phosphorus concentrations in open water; GLWQA objectives were achieved by 1990 in all lakes then fluctuated near the limit for Lake Erie during 1991-92 (see Figure 12). The 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 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 have fish consumption advisories. The report also showed 24 of the 42 AOCs have beach closures or recreational body contact restrictions.

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 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.

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

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

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. The 11 substances are listed in Table 4 together with several others identified for priority consideration. While these have been recommended for priority consideration, there are numerous other substances which must also be considered because of their known or suspected impact on the ecosystem and human health.

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 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 early pioneering days, as measured by longevity, or in the incidence of fatal or crippling infectious diseases such as poliomyelitis or typhoid fever. However, much of that improvement is the result of improvements in sanitation, vaccines and drinking water disinfection. On the other hand, there have been slow, but steady increases in the incidence of certain cancers and 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 environmental contaminants on human health need further investigation.

Comparing the Great Lakes basin with other areas, 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. Table 5 shows a comparison of PCBs in breast milk between the Continental U.S. and the Great Lakes region. Although the contaminant levels in Great Lakes residents are comparable to other areas, this does not mean that they are acceptable.

6.0 SOCIO-ECONOMICS

Growth of the North American economy followed the arrival of European people with their intensive agriculture, resource exploitation, urbanization and exotic fauna and flora. The result of this growth has been a significant disruption of the ecosystem. Conversion of native forests and prairies to agriculture had an immense impact on the native fauna and flora throughout the region. Urbanization with its intensive land uses and transportation facilities provided further impacts. Today's continuing urban sprawl adds to the stress on the ecosystem. On the other hand, the strength of the economy provides the resources and potential to restore and maintain the integrity of the ecosystem.

Historically the Great Lakes and their tributaries provided access and transportation for development of a major portion of the inland area of the North American continent. The agricultural and mineral wealth of the region then fuelled the development of an economy that included a major concentration of iron and steel production and metal fabricating. This in turn spawned a large cluster of durable goods manufacturing. Machinery, transportation and other equipment, appliances, construction materials and motor vehicles became manufacturing mainstays. Industries of the Great Lakes region today continue to rely on water. Water use in manufacturing is concentrated in 5 sectors: steel production, food processing, petroleum refining , chemicals and the paper industry. Although industrial water use is now declining, water from the Great Lakes supplies more than three-quarters of the industrial demand in the basin.

The Great Lakes basin represents nearly 11% of total employment and 15% of manufacturing employment for the two nations. However, the economy of the region has slowed in recent decades and has been shifting away from its historic concentration in manufacturing. From 1970 to 1990 the basin lost nearly 21% of its manufacturing jobs (Figure 15). In contrast, total manufacturing jobs throughout Canada increased by 22% and held nearly steady throughout the U.S. with a 0.3% gain. This has caused a dramatic redistribution of employment within the basin. During this same time period service sector jobs have increased by just over 100% with more than 2 million jobs added in the basin.

The regional economy is strongly integrated and is the largest such binational relationship in the world. Trade between Canada and the eight Great Lakes States in 1992 was valued at $148 billion Can. ($106 billion U.S.) — see Figure 16, or 56.2% of the U.S. — Canada total. Three-fifths of this was in autos, auto parts and engines. On a national scale, Canada accounts for one-fifth of U.S. trade and in turn the U.S. receives two-thirds of Canada's exports.

Population within the region is distributed unevenly and is concentrated in metropolitan areas. Approximately three-quarters of the population is concentrated in the Lake Michigan and Lake Erie basins. Another one-fifth is in the Lake Ontario basin and the remaining tenth in the Huron and Superior basins (Figure 17).

The majority of the basin population is located within the 17 largest metropolitan areas most of which are on the shores of the Lakes. Six areas contain 75% of Canada's Great Lakes population and 11 contain 81% of the U.S. basin population. Total population of the Great Lakes basin is approximately 33 million, although estimates can vary depending on how much of the Chicago metropolitan area population is included based upon current or historic watershed boundaries.

Population growth in the recent decades has slowed. While the combined population of the U.S. and Canada grew by 22% from 1970 to 1990, rising from 225 million to 275 million, the binational 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 prescribed boundaries and existing infrastructure capacity as is done in some other countries.

Agriculture in the Great Lakes basin is both diverse and productive, and is a major part of the overall economy not only of the basin but also of the two nations. With respect to value and volume, dairy, cash grain and livestock sales are the region's agricultural mainstays. In addition, the region has a wealth of specialty crops, attributable to small unique climatic zones. Since farming depends on the vagaries of weather, the Great Lakes basin agricultural productivity could be jeopardized if significant climate change occurs. Other issues of concern for the region include the use of chemicals and soil erosion. More than 57 million tonnes (63 million tons) of soil erode annually in the U.S. portion of the Great Lakes basin. This results in reduced agricultural productivity (lower yields), increased fertilizer use, and also causes increased sedimentation of streams and tributaries.

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 estimated that between 900,000 and 1 million U.S. and Canadian boats operate each year with a direct spending impact of more than $2.8 billion Can. ($2 billion U.S.). With a strong connection to boating, Great Lakes sport fishing is a major part of regional fishing activity. U.S. federal surveys projected 2.55 million U.S. anglers fished in the Great Lakes in 1991 and had total trip-related and equipment sales expenditures of $1.86 billion Can. ($1.33 billion U.S.). Expenditures per angler were calculated at about $700 Can. ($500 U.S.) for the year.

Economic activity produces both stresses on the ecosystem and the means to address or mitigate them, so economic indicators should be viewed from that perspective.

Ten economic indicators were selected. Two of these were rated as poor-infrastructure investment and loss of agricultural land and urban development. Public infrastructure includes roads, sewers and water supply systems. This rating reflects the continuing low levels of government investment in basic infrastructure. An exception is the expenditure of $14 billion Can. ($10 billion U.S.) in sewage treatment plant construction and sewer system upgrades in both countries during the past two decades as a direct result of the GLWQA. A poor rating was also given to land use changes because of the continuing trend to urban sprawl and the loss of agricultural land.

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%. Research and development are measures of technological innovation, an area that has recently faltered in the manufacturing industry. However, the emergence of a substantial “environmental industry” sector including resource conservation, pollution remediation and reduction technology and other goods and services intended to help the economy reduce its negative impact on the physical and social environment, may soon see this indicator change to a mixed/improving rating.

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%.

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

6 for a listing of beneficial use impairments). Using a comprehensive and coordinated ecosystem approach, the Parties will also be examining other ecosystem stressors, so that a truly ecosystem-based management program can be developed and delivered. There is also a commitment to develop and implement Remedial Action Plans (RAPs) in partnership with state/provincial and municipal governments and other local stakeholders including industry, indigenous peoples and the public. The primary purpose of the RAPs is to restore the environmental quality in the 42 Areas of Concern (AOCs) in the Great Lakes basin ecosystem. In addition, under the auspices of the Great Lakes Fishery Commission, state and provincial fishery management agencies are developing joint management plans. The Great Lakes Fishery Commission was created in 1955 with the signing of the Convention on Great Lakes Fisheries. In 1980 fisheries management agencies formally organized their inter-jurisdictional activities by signing "A Joint Strategic Plan for Management of Great Lakes Fisheries" also known as the Strategic Great Lakes Fisheries Management Plan (SGLFMP). It committed fishery management agencies to develop a set of fish community objectives and associated environmental objectives for each of the Lakes. The SGLFMP call for environmental objectives relates well with the 1978 Great Lakes Water Quality Agreement call for an ecosystem approach. Potential linkage with SGLFMP was strengthened in 1987 with Agreement provisions calling for development of ecosystem objectives and indicators.

Fishery management agencies and water quality management agencies are beginning to work together to achieve the common objectives of RAPs, LaMPs and fishery management plans, but much remains to be done in joining the separate histories and expectations of the agencies and professions involved.

Fishery management agencies have, over the past 100 years, been involved in stocking programs. These programs were originally the direct result of the depletion of fish stocks caused by overfishing, and more recently due to loss of habitat and most devastatingly, the invasion of sea lamprey. Another major reason for stocking was the need to control nuisance populations of alewife. The stocking strategies involved primarily the lake trout and coho and chinook salmon. Salmon were selected because they mature, spawn and die in four years, and the populations were able to withstand lamprey predation better that the slower growing lake trout. The salmon stocking program has been very successful, and has resulted in a very valuable sport fishery. While there is some natural reproduction of these salmon in the Lakes, the fishery remains largely “put and take”. Lake trout stocking has, to date, been less successful. There is little natural reproduction of lake trout except in Lake Superior and a few remnant stocks in Lake Huron. Loss of lake trout spawning habitat may be a significant factor in this failure.

7.1 LAKE SUPERIOR

Lake Superior is the largest of the Great Lakes in both surface and volume. It is also the deepest and coldest of the five. In volume Superior could contain all the other Great Lakes and three more Lake Eries. Among the lakes of the world, Lake Superior is the largest freshwater lake in area. In volume, it is the third largest in the world. Because of its size, Superior has a retention time of 191 years. Retention time is a measure of the volume of water in the Lake and the average rate of flow out of the lake. Additional information on Lake Superior can be found in Table 1.

The basin population is approximately 740,000 which is 2% of the total for the Great Lakes basin. Approximately 75% of the Lake Superior population lives within the U.S. The population and industrial base is small, and most of the Superior basin is forested with little agriculture because of the cool climate and poor soils. Relatively small quantities of pollutants enter Lake Superior directly, except through airborne deposition.

In terms of environmental quality, Lake Superior is distinguished by its high quality compared to the other Great Lakes and many parts of the U.S. and southern Canada. This is due in large part to the relatively small population and very limited industrial base. Notable exceptions to this high quality are the seven Areas of Concern where beneficial uses including the aquatic communities are impaired. AOCs include- the lower reach of the St. Louis River/Bay near Duluth, MN and Superior, Wisconsin; Thunder Bay, Ontario; and the smaller areas of Jackfish Bay, Nipigon Bay and Peninsula Harbour in Ontario and Torch and Deer Lakes in Michigan. Progress is being made in restoring beneficial uses to all of the AOCs as reported in <u>Progress in Great Lakes Remedial Action Plans: Implementing the Ecosystem Approach in Great Lakes Areas of Concerns</u> and as seen in Table 6.

Most of the losses within the aquatic community occurred in previous decades during exploitation of natural resources, particularly excessive fisheries harvests followed by impacts of the sea lamprey. The most severe and permanent loss has been to the lake trout population which lost many genetic stocks, most notably all those that spawned in tributaries. Although the remaining stocks are reproducing naturally, the population has not yet become fully self- supporting, since hatchery fish are still needed to supplement natural reproduction.

Despite genetic losses within fisheries stocks, biodiversity within the Lake Superior basin is relatively unimpaired compared to the other Lakes. Tributary habitat is degraded in many areas, but there are also large tracts of very high quality habitat. The challenge in Lake Superior is to preserve the relatively high quality areas that exist throughout the basin. In terms of stressors, the greatest threats to the aquatic community at present are the river ruffe and sea lamprey. Ruffe is an exotic species with no commercial or sports value, introduced into Duluth Harbor in ballast water from transatlantic cargo vessels. It is steadily spreading through near shore waters and it is feared that it will 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 states and the province by species and size of fish. The public is advised not to eat the siscowet form of lake trout at any time and to limit consumption of other lake trout, brown trout, steelhead, coho salmon, chinook salmon, white fish, walleyed pike, smelt, and lake herring. The recommended limits for frequency of consumption differ by species and by political jurisdiction, so it is important for consumers to consult consumption guides in their respective jurisdictions.

Despite the foregoing, Lake Superior is still considered to be the most pristine of all the Great Lakes. The International Joint Commission (IJC) called on Canada and the U.S. in 1989 to declare Lake Superior an area where no further point sources of persistent toxic chemicals would be permitted. The Parties responded in 1991 with the Lake Superior Binational Program. This calls for the water quality to be maintained and enhanced, to protect, and where necessary, restore the integrity of Lake Superior's ecosystem, as well as outlining a zero discharge demonstration project for nine critical toxic substances from point sources. An action plan has been developed and many actions have already been taken to move towards zero discharge. However the effectiveness of the zero discharge program in eliminating the impacts of persistent toxic substances also depends upon the effectiveness of programs to deal with the airborne deposition of these substances.

The Binational Program is evolving and broadening to include all of the elements of a Lakewide Management Plan as well as natural resources, habitat, exotic species and biodiversity issues. It is building upon the ecosystem objectives and indicators identified in the Great Lakes Water Quality Agreement and also upon fish community objectives developed in response to the Strategic Great Lakes Fisheries Management Plan.

The background and problem definition portions of the LaMP are nearing completion for critical pollutants, other stressors and ecosystem objectives and are to be presented to the IJC by September 1995. A schedule of necessary load reductions for critical pollutants is being developed and will be provided to the IJC following public comment.

7.2 LAKE MICHIGAN

Lake Michigan, the third largest in area, is the only Great Lake entirely within the United States. It is the fourth largest freshwater lake in the world in terms of area and fifth largest in terms of volume. Water retention time in the Lake is estimated at approximately 100 years.

The northern part is in the colder, less developed upper Great Lakes region. It is sparsely populated, except for the lower Fox River Valley which drains into Green Bay. This Bay has one of the most productive Great Lakes fisheries but receives the wastes from the world's largest concentration of pulp and paper mills. The more temperate southern basin of Lake Michigan is among the most urbanized areas in the Great Lakes system. It contains the Milwaukee and Chicago metropolitan areas. This region is home to about eight million people or about one-fifth of the total population of the Great Lakes basin. The basin as a whole has a population of approximately 14 million. Fortunately for the Lake, drainage for much of the Chicago area has been redirected out of the Great Lakes basin. For additional information on Lake Michigan see Table 1.

Environmental quality in the basin generally follows a north south gradient, being best in the north and degrading to the south. There are ten Areas of Concern around the Lake where the worst degradation exists (see Table 8). In terms of magnitude, the Indiana Harbor, Milwaukee and Green Bay AOCs are the largest and most degraded although the Kalamazoo River contains very large quantities of PCBs. Manistique, Menominee, Sheboygan, Muskegon and White Lake are less degraded, but still have beneficial use impairments.

The aquatic community in Lake Michigan has undergone huge changes. The fishery was very productive until over fished and decimated by exotic species. The sea lamprey eliminated all stocks of lake trout and severely depressed whitefish and other populations. Lamprey populations declined substantially after control measures were implemented in the 1960s, thus allowing for the increased survival of the stocked trout and salmon. Current increases in lamprey wounding rates of lake trout in northern Lake Michigan are thought to be a result of the proximity to the St. Marys River.

Alewife populations exploded in the absence of predators; and during the die-offs of the 1950s and 1960s were estimated to constitute as much as 90% of the biomass in the Lake. Coho salmon, chinook salmon, rainbow trout and brown trout were stocked to support a sport fishery and control alewife through predation. Alewife populations have decreased to 20% or less of their former abundance as a result of poor over-winter survival and predation from the stocked predators. As a result, native burbot, yellow perch, and bloaters have made a spectacular recovery since the early 1980s. Bloaters are now more abundant than alewife were in the 1970s.

Algae and zooplankton populations have also undergone major changes due to changing predation by fish, changes in water quality and invasion by exotic species such as the spiny water flea and zebra mussels. What the long term aquatic community will be, remains unknown.

The sport fishery remained productive until the mid 1980s when a bacterial kidney disease (BKD) outbreak reduced the abundance of chinook salmon by 50% or more. Sport fishing effort also dropped by more than 50% in some states because chinook salmon comprised the majority of the sport catch. The cause of the BKD outbreak remains unknown. In addition, a sharp decline in the survival of coho salmon eggs in hatcheries began in the early 1990s. This lack of survival was 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 pollutants. Also, further efforts are underway to strengthen the science base for dealing with contaminants.

To obtain better information on the sources, loadings and behaviour of toxic contaminants the U.S. Environmental Protection Agency together with various state and federal agencies are conducting Lake Michigan Mass Balance Study. The study is seeking to determine how toxic 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. For addition information on Lake Huron see Table 1.

Lake Huron is literally the lake in the middle, both geographically and in environmental quality. It has relatively good quality of water and wetlands except in the Areas of Concern. The fishery is relatively healthy except for the lamprey threat from the St. Marys River, discussed later in this section. Originally, there were five AOCs on Lake Huron. One of them, Collingwood Harbour, has since been cleaned up and was taken off the list of AOCs in 1994. The binational St. Marys area at the head of the Lake was originally designated because of contaminants, but is also a major and growing source of lampreys. Control of industrial sources is progressing and pollution loads are being reduced. The two other Canadian AOCs, Spanish River and Severn Sound are responding well to remedial actions and showing recovery (Table 9).

The remaining AOC is Saginaw Bay. The Bay is a rich biological resource and is the largest freshwater coastal area in the U.S. with a water surface of 1,143 square miles (2960 square kilometres). Biodiversity of the Bay and its watershed remains quite high although 138 plant and animal species have been identified as endangered, threatened or of special concern. The area continues to provide essential habitat for both fish and wildlife with more than 3 million waterfowl migrating through the area annually.

Historically there were approximately 37,000 acres (14,800 hectares) of emergent marsh around the Bay, but less than half remains. Throughout the watershed, wetlands originally covered approximately two thirds of the basin but now cover only about 15%.

The Bay receives runoff from an 8,700 square mile (22,530 square kilometre) watershed that contains 1.4 million people, approximately 35% of the population of the entire Lake Huron basin. The watershed of the Bay also contains large amounts of industry and intensive agriculture. As a consequence, it has received heavy loadings of nutrients and toxic contaminants. Loadings have been reduced, but problems of contamination and eutrophication continue, partially due to recycling of old deposits.

In addition to human stresses, the most recent problem, the zebra mussel invasion, has the potential to significantly impact biological communities and contaminant cycling in the Bay.

For the remainder of Lake Huron, aquatic community health and biodiversity is perceived as being relatively good, at least in contemporary terms and in comparison to the other Lakes. The forage fish population appears to be healthy. Walleyes are recovering locally in both Saginaw Bay and Severn Sound. Whitefish have recovered and are at historically high levels. However, there is some concern over whether current levels of walleye are sustainable, particularly with growing populations of lampreys and unknown food chain impacts resulting from zebra mussels. There is also concern over the continued health of other large fish in northern Lake Huron due to the threat of lamprey. Additionally, lake trout populations are still not self sustaining. They are genetically impoverished and rely on hatcheries for reproduction. Declining walleye populations in Georgian Bay are another concern.

Consumption advisories with respect to amount and frequency of consumption are in effect for chinook salmon, coho salmon, brown trout, steelhead, walleyed pike and yellow perch. As in other lakes, advisories differ by species, size and location so it is important to check advisories in effect for the appropriate state or provincial jurisdiction.

Lake Huron is the most important Lake of all the Great Lakes in terms of having the highest number of fish-eating birds that breed along lake shorelines. This is due to the diversity and areal extent of habitats available to the birds on the Lake. Most populations of the fish-eating breeding birds are increasing, for example cormorants, caspian terns, and osprey. Pairs of bald eagles have returned to nest along the Lake Huron shoreline. The herring gull population is declining in a few areas on the Lake but this is probably due to changes in the fish community structure rather than contaminants. Caspian terns and osprey are no longer showing adverse effects of contaminants, however, they are not as sensitive to the current contaminants as other species. Loss of shoreline marshes and wetlands have been moderate compared to the other Lakes except in Saginaw Bay. However, continuing loss of wetlands along the shores and tributaries is a serious threat to habitat, one aspect of which is loss of 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-middle”, it is the lake without high-profile issues or advocacy groups to focus attention on it. Nonetheless, the problems are real and there is a need to identify what most needs to be protected and restoration. A plan for action is then needed to address the problems. Fish community objectives have been approved, but there is currently no LaMP structure in place and is unlikely to start before 1998 due to a scarcity of resources. What is needed is a process for developing a Lakewide Management Plan that includes both environmental quality and fisheries management.

7.4 LAKE ERIE

Lake Erie is the smallest of the Lakes in volume and second smallest in area. Yet it is still the tenth largest freshwater lake in the world in terms of surface area and 16th in volume. Of all the Great Lakes it is exposed to the greatest stress from urbanization and agriculture. The Lake receives runoff from the rich agricultural lands of southwestern Ontario and parts of Ohio, Indiana and Michigan. Seventeen metropolitan areas of over 50,000 population are located within its basin. The basin population is approximately 13 million with approximately 88% of the population within the U.S. For Additional information on Lake Erie see Table 1.

There are eight Areas of Concern on Lake Erie (Table 10), but four more from the Detroit and Sarnia areas contribute to its problems. The Buffalo AOC has little affect on the Lake as most of its discharge is drawn into the Niagara River and into Lake Ontario. Presque Isle, Pennsylvania and Wheatley Harbour, Ontario are relatively small, but the others are major problem areas. The Ashtabula, Cuyahoga, Black, Maumee and Raisin River areas all present formidable problems as do the St. Clair, Clinton, Detroit and Rouge River areas upstream.

The Lake is large in area, but the average depth is only about 19 metres (62 feet). It is the shallowest and therefore warms rapidly in the spring and summer and frequently freezes over in winter. It also has the shortest retention time of the Lakes, 2.6 years. The western basin, comprising about one-fifth of the Lake, is very shallow with an average depth of 7.4 metres (24 feet). The waters of the Lake, like the surrounding farm lands, are highly productive; far more productive than the other Lakes.

Although the Lake Erie basin is the most intensively populated and farmed, pollution loading has been mitigated through sedimentation from the productive algae and fine soil particles from farmland erosion. Therefore, with respect to toxic contaminants, Lake Erie organisms have historically shown relatively low concentrations compared to the other Lakes. As eroded soil and nutrient levels decline and zebra mussels deplete algal populations, this may change, increasing rates of bioaccumulation.

In terms of environmental quality, Lake Erie is severely degraded with respect to habitat. Although never "dead" as reported in the 1960's, it was severely stressed by eutrophication stimulated by excess nutrients. The resulting algal blooms closed beaches, disrupted food chains and aquatic communities, and caused wide spread oxygen depletion in the central basin. Massive investment in municipal and industrial waste treatment and voluntary programs to control agricultural land runoff have produced excellent results. They have achieved target levels and are producing the biological results expected. Oxygen depletion still occurs in the bottom waters of the central basin, but to a diminishing extent. Phosphorus concentrations in the western basin have nearly reached target levels but sediment resuspension during storms results in recycling of nutrients from bottom deposits.

The near total removal of native vegetation from the basin, and severe exploitation of fisheries followed by exotic species invasions, have devastated the original aquatic community of the Lake. Recovery is under way, but the long term nature of the resulting community is unknown. Species having particularly heavy impact include zebra mussels, and carp. Others such as alewife, smelt, white perch, pacific salmon, and most recently the round goby have added stress to the system.

Zebra and quagga mussels are closely related exotic species that prefer habitats typical of Lake Erie. The two species are very similar, a major difference being that quagga prefer deeper water than zebra mussels. Without any natural predators or diseases, their populations have exploded. Both mussels are voracious filter feeders, and as such, have had profound effects on the Lake’s ecosystem including abrupt changes in water quality, water clarity and the food web.

By consuming large amounts of phytoplankton, they have increased water clarity (a 77% increase in water transparency has occurred between 1988 and 1991). By increasing the clarity of the water, sunlight is able to penetrate deeper, allowing rooted aquatic plants to spread into deeper water. This has had ecological benefit to many organisms but has interfered with swimming and boating in some areas.

The eating habits of mussels have led to large changes in the food web which may result in major changes in the future abundance of various species of fish. They have depleted the food source (phytoplankton) for other filter feeders, and have also assimilated toxic contaminants. By removing large amounts of particulates, which formerly absorbed/adsorbed pollutants, more contaminants are left in the water. This could result in higher contaminant concentrations in the remaining phytoplankton and zooplankton as well as higher concentrations in fish and wildlife species feeding on the plankton or directly on the mussels and other benthos (bottom dwellers). The results of the zebra mussel invasion have become far more complex than the physical problems of clogging intake pipes or jamming machinery.

Although not yet established in Lake Erie another exotic species to be concerned with is the ruffe. Ruffe habitat consists of warm shallow water such as found in much of Lake Erie. In fact, considering all of the Great Lakes, Lake Erie has over half the thermally suitable habitat. Potential effects of large populations of ruffe on fish communities are unknown, but if it were to become as abundant in all the thermally suitable habitat as it did in the St. Louis River estuary of Lake Superior, it would be a major problem for the Great Lakes fisheries. A decline in the yellow perch abundance similar to that seen in the St. Louis River estuary would seriously impact the fishery which is presently valued at $141 million Can. ($101 million U.S.) in Lake Erie alone for yellow perch.

Historically, the top commercial fish in Lake Erie included whitefish, walleye, blue pike, lake trout (only found in the eastern basin of Lake Erie in the colder deeper waters) and sturgeon. The demise of the lake trout was mainly a combination of overharvesting and environmental stress. The populations of whitefish, walleye and sturgeon have diminished from overfishing and blue pike became extinct. In 1970 high levels of mercury led to the closure of the commercial walleye fisheries in the U.S. and Canada as well as restrictions on the retention of walleyes caught by anglers. After 1972 the mercury levels had declined and the walleye fishery re-opened in Ontario to both sport and limited commercial use; however in Michigan and Ohio it was restricted to angling. Due to the relief from commercial fishing and to the quotas imposed after re-opening the fishery, the walleye fishery of the western basin has shown a spectacular recovery.

Some fish consumption advisories are in effect for lake trout, chinook salmon, coho salmon, walleyed pike, smallmouth bass and white bass. As in other lakes, advisories differ by species, size and location so it is important to check with the appropriate state or province.

A LaMP (Lakewide Management Plan) is currently being developed for Lake Erie, in accordance with the GLWQA, between the Canadian and U.S. federal governments, the four Great Lakes states (Ohio, Michigan, Pennsylvania, and New York) and the province of Ontario. The goal of the LaMP is to restore and protect the beneficial uses of Lake Erie using an ecosystem approach. It will address critical pollutants, habitat loss, exotic species and natural resource management including fish community objectives. Fish community objectives are being developed in response to the Strategic Great Lakes Fisheries Management Plan and are currently under review.

Four critical pollutants have already been identified for immediate action: PCBs, DDT and metabolites, chlordane, and dieldrin, and the remainder of pollutants will be identified through the beneficial use impairment assessment. LaMP activities will closely coordinate with the Remedial

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.

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 rapidly in the 1970s and early 1980s but since that time contaminant levels in the biota have declined much more slowly or even, in a few cases, increased (Figure 21).

Mirex and photomirex are contaminants whose impacts are mainly confined to Lake Ontario fish and fish-eating birds, although very low levels (100-200 times less) have been found in Lakes Erie and Huron birds and fish. Mirex concentrations in fish have declined significantly since the 1980s in Lake Ontario. Increases were observed in 1991 and 1992, but they are thought to be the result of changes in the food chain rather than increased loadings to Lake Ontario. Nevertheless the concentrations remain high enough to be the basis for some fish consumption advisories.

In Lake Ontario consumption advisories are in effect for lake trout, chinook salmon, coho salmon, brown trout, rainbow trout, walleye, white sucker and white perch. As in the other Lakes, advisories differ by species, size and location, so it is important that consumers check with the appropriate state or province.

The present fishery of Lake Ontario is maintained by stocking hatchery reared fish, primarily pacific salmon. Originally introduced to control alewife they have become the basis of an economically important sport fishery.

However, there is a question as to whether reliance of hatcheries on non-native fish can be naturally sustained in the long term.

In 1984, the management agencies of the Lake Ontario fishery stocked 8.2 million fish. Since that time, they have recognized that there is not enough food to sustain this amount of stocked fish. It is estimated that Lake Ontario will support 4-5 million of "put and take" fish added each year. As a result the agencies have decreased the amount of fish stocked in Lake Ontario each year so that by 1994 the amount stocked was almost half that of a decade ago (4.5

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 restore them.

Habitat and biodiversity losses continue, most notably due to urban sprawl and agricultural practices. The bald eagle illustrates the combined effects of habitat loss and toxic chemicals on birds of prey. Bald eagles were extirpated from many of the islands and shorelines of the Great Lakes in the 1950s and early 1960s due to effects of DDT (causing egg shell thinning). However, prior to widespread use of DDT, eagle populations were already in decline. The loss of nesting habitat, changes in fish populations, and persecution by humans were some of the reasons for their initial decline. Together the remaining contaminant levels and the lack of habitat (mature eagles favour coniferous perches away from human disturbance) have resulted in little success in the return of the bald eagle to the Lake Ontario shoreline. The eagles have been more successful inland from the Lake.

The problem of persistent toxic contaminants in the Lake led federal and provincial/state governments to develop the Niagara River Toxics Management Plan (NRTMP). Following this, the Lake Ontario Toxic Management Plan (LOTMP) was developed. These plans were developed to reduce the loadings of contaminants into Lake Ontario.

The most significant sources of toxic chemicals in Lake Ontario are considered to be the Niagara River (which also includes the entire Great Lakes drainage basin upstream of the Niagara River); inputs from the ten other major tributaries; non-point sources (including surface water runoff and atmospheric deposition); and inputs from point sources (municipal and industrial facilities discharging directly into the Lake). Since the Niagara River constitutes nearly 85% of the tributary flow into Lake Ontario, and since it is heavily industrialized, it is a significant source of most of the toxic chemicals entering the Lake.

The LOTMP is currently being expanded into a more ecosystem based LaMP to protect the Lake and to focus on restoring beneficial uses. This will be achieved using indicators, that are representative of a healthy self-sustaining ecosystem, to identify the pollution problems and to further determine the areas of degraded quality. Fish community objectives for the Lake have been developed, but continue under review based on public comment. These objectives will be used as one 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 of the Great Lakes for future generations. These challenges include:

The challenge of adequate information: This report, and the background papers on which it is based, cite numerous examples of areas in which research and data collection need to be done. In many cases, however, the amount of research necessary is overwhelming relative to the resources available. Some priority research needs include data on the quality and quantity of aquatic habitat, information on atmospheric transformation and deposition to aid in the determination of pollutant loadings to each of the Great Lakes, information on contaminant cycling, a better understanding of food web dynamics, spatial and temporal data on humans and aquatic biota, and basic economic data on the Great Lakes basin. Effective steps forward require good information on stresses, interactions and effects on which to base decision-making. 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 not readily available. Moving forward to restore ecosystem health will require taking advantage of the tremendous strides made in computer networks, integrated information, cable, and other telecommunication opportunities to improve communication on environmental issues. Effective communication is key in transferring scientific knowledge to the policy makers in a useful and understandable language. For this to happen the data must first become consolidated, standardized and accessible.

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 often at the local level. The ecosystem approach to decision-making is at work in the LaMPs and RAPs programs.

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. Each agency has its own goals, objectives and mandates, 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 preference and how much they are willing to pay to achieve their objectives. Scientific advice should contribute to an informed decision-making process. Lake Erie provides us with a good example. The historic ecosystem of Lake Erie no longer exists, and is unlikely ever to exist again. The ecosystem is more fragile now and the goals must be redefined based on the impacts of zebra mussels, loss of habitat and contaminants. The major shifts in the biological community structure make predictions about the future status of the ecosystem highly uncertain.

While it is important to define benchmarks and to achieve societal consensus on the desired endpoints for restoration, managers must also know when it is best to act on behalf of the lake. Again using Lake Erie as an example, during the mid-1980s when water levels on the Lake were quite high and damage to shoreline properties occurred with every storm, the public wanted regulated water levels. Managers were able to convince them that it was better for the ecosystem to regulate its own water levels.

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 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?

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 enviromental quality, resource management or other purposes. However, it must be remembered that because of the complexity of the ecosystem, outcomes can never be predicted with absolute certainty, and can often be entirely unpredictable.

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 social needs of humans in a balanced and sustainable manner. The Great Lakes basin and surrounding region face a future filled with opportunities as well as uncertainties. A sustainable development course will require new measures to enhance economic growth as well as institutional mechanisms among public and private sectors designed to foster cooperation and coordination in environmental protection. There is a continued need on the part of governments and industry to prevent pollution problems before they arise.

The connection between the quality of the environment and viability of economic systems has been recognized by some for a long time, but it was given new meaning and immediacy in 1987. <u>Our Common Future</u>, the 1987 report of the World Commission on Environment and Development coined the term "sustainable development", defining it in terms of a way of life that meets the needs of the present without compromising the ability of future generations to meet their own needs. This in turn clearly requires prudent management of resources including maintaining the integrity of ecosystems.

The concept received global recognition and support in the 1992 United Nations Conference on Environment and Development. Following the conference individual countries, including Canada and the U.S. have identified sustainable development as a goal and taken various steps to attain it.

In 1991 the Chairman of the Council of Great Lakes Governors described a vision of the region as a world leader in natural beauty and economic might. It is a vision that recognizes that the restoration and protection of the Great Lakes is dependent upon a world-class economy. At the same time it recognizes that the health of the Great Lakes is central to the region's economic future. The vision also recognizes that the region's industries will not be competitive in the world economy, unless they are world leaders in clean, sustainable production.