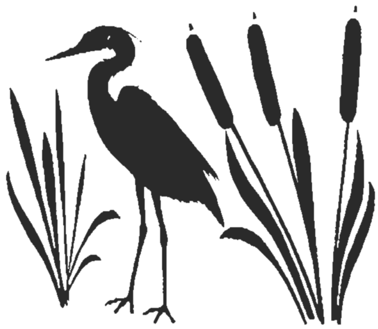
S.O.L.E.C.

1994 State of the Lakes Ecosystem Conference Background Paper



Aquatic Habitat and Wetlands of the Great Lakes

August 1995

Environment Canada
United States Environmental Protection Agency
EPA 905-R-95-014

State of the Great Lakes Ecosystem Conference

Background Paper

AQUATIC HABITAT AND WETLANDS OF THE GREAT LAKES

Doug Dodge
Ontario Ministry of Natural Resources
Maple, Ontario

Robert Kavetsky
U.S. Fish and Wildlife Service
East Lansing, Michigan

August 1995

CONTENTS

NOTICE TO READER

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

The Background Papers were first released as Working Papers to provide the basis for discussions at the first State of the Lakes Ecosystem Conference (SOLEC) in October, 1994. Information provided by SOLEC discussants was incorporated into the these final SOLEC background papers. SOLEC was intended to provide key information required by managers to make better environmental decisions.

EXECUTIVE SUMMARY

Aquatic habitat loss and degradation is insufficiently documented. Data that would shed light on the larger picture and its repercussions are almost non-existent. Instead, there are numerous local studies, split by watersheds, jurisdictions and disciplines. The assessment of the state of the habitats remains almost entirely anecdotal. However, the sheer number of anecdotes and their basic agreement allow only one conclusion: that habitat loss and degradation in the Great Lakes basin have been very high, especially in the highly productive and diverse inshore zone and the connecting channels.

By and large, the open Lakes are recovering from the eutrophication of the last decades. However, many species associated with them remain threatened because the inshore, shoreline and tributary habitats which they also require have been lost or impaired. The dependence of the lakes and the species that are associated with them on healthy shoreline, inland and tributary habitats has been largely neglected. As a result, the impoverishment of these habitats has hardly registered as a Great Lakes issue.

Most habitat losses to physical changes (e.g. filling, bulkheading, etc.) are likely irreversible, while losses caused by biological and chemical changes have the potential to be reversed. Accordingly, it makes sense to focus on stopping the ongoing pattern of loss and impairment. Present losses are rarely the large-scale conversion of habitat to other uses; degradation is more common, in a variety of subtle guises that truly require an ecosystem approach to understand and reverse.

In recognition of the interrelated nature of living systems and their habitats, there is a growing realization of the need not only to protect the species that are in imminent danger of extinction, but to consider the entire picture and anticipate threats of extinction long before they become acute. To do this it is necessary to consider entire ecosystems, not just artificially separated fragments of them. Consideration of habitat is an essential component of this approach.

Clearly the health of habitat and wetlands is a major concern in the Great Lakes Basin. A number of programs, laws and policies already exist to enhance habitats in the Great Lakes Basin. What is needed to better protect and restore wetlands and other aquatic habitats is probably not more laws, but rather stronger will to conserve habitats, and implementation and enforcement of existing laws, regulations and policies. Coupled with this need for improved implementation and policy is the need for a strategic approach to habitat protection and restoration, making full use of all levels of partnerships.

1.0 Introduction

Concern about habitat and especially wetland loss in the Great Lakes Basin has grown in recent years. Protecting and restoring Great Lakes habitats requires an understanding of the importance of healthy habitat in sustaining human and all other life. This understanding is necessary both at the level of the whole basin, and for the individual habitats within the basin. If the habitats of the Great Lakes are like a great life-supporting net, we need to know where the holes and weak spots are so that we may give them our attention first. Because the Lakes are part of such a vast ecosystem, and action to protect, preserve and restore it is needed in so many areas, it is critical to take bearings, and to understand the linkages in order to inform and guide this work.

For the purposes of this paper habitat means that space that is or can be successfully occupied (inhabited) by a species or biotic community or some broader (taxonomic or phylogenetic) entity. Habitat is simply the place where an organism or group of closely related organisms live. The goal of habitat preservation can only be described in terms of those biotic entities. This paper provides the basis for discussion of the habitat values of the Great Lakes by addressing the following questions:

1. What habitat types are there and how are they linked?
2. By what criteria can the significance of a habitat be judged?
3. How significant are each of the habitat types?
4. Which habitats are most threatened by which human actions?
5. How adequate are current efforts to preserve and restore habitat?
6. Where do current actions and future initiatives need to focus in order to ensure a healthy web of habitats capable of supporting a diversity of life of the basin?

The answers to these questions remain incomplete.

2.0 Habitat Types in the Great Lakes

For the purposes of this paper, habitats of the Great Lakes have been divided into the following types:

- Open-lake
- Coastal wetlands
- Shoreline
- Tributaries
- Connecting channels
- Inland habitats

Numerous classification systems exist, and their diversity speaks to the fundamental problem that plagues such systems - habitats that belong together are often classified separately and others, quite distinct, are clustered together. The scheme chosen for this paper is a hybrid of other systems based on spatial distinctions. The reality of gradients and close linkages should not be confused with the usefulness of a model as a basis for organizing discussion.

The habitat classification used here differs from the distinctions recently proposed by the Nature Conservancy (1994), and highlights the differences between tributaries and connecting channels, and includes inshore areas other than wetlands. The number of inland and shoreline habitat categories has been reduced to allow a greater focus on the lakes themselves.

Other classification systems have been created for a variety of purposes: a brief discussion of the opportunities and obstacles created by numerous systems is found in Section 6.1 below.

Each of these broad habitat categories includes a range of habitat types. In general, the natural distribution of habitat types within the Great Lakes depends on lake bed and shore topography, geology and climate.

2.1 Open-Lake

The open lake includes both the inshore and offshore waters of the lakes. The inshore waters begin at the offshore edge of the coastal wetlands and extend lakeward to the point where vertical thermal stratification can be measured in summer. This point, where the thermocline intersects with the lake bed, is usually taken as the boundary between the inshore and offshore waters. This boundary is dynamic and moves progressively farther offshore and into deeper water as the summer progresses. Minor differences in water depth and distance from shore at the boundary location can occur between lakes and in response to local hydrologic conditions within each lake and at any point in time. At the end of summer the thermocline may be as deep as 30 meters in Lake Michigan.

Fish are the dominant fauna of the open lake. During the summer, coldwater fishes including trout, salmon, and whitefish occupy the deeper, colder offshore waters, while cool- and warmwater fishes inhabit the shallower, warmer, inshore waters. Phytoplankton occupy the upper layers of the open lake and benthic algae colonize the shallower portions of the lake bed where sunlight is sufficient to support photosynthesis. Light penetration may extend only a meter or less in some areas and to more than 60 meters in others. Zooplankton colonize the open lake from the surface of the water to the lake bed, and productive and diverse benthic invertebrate communities occupy the lake bed wherever it has not been degraded.

Most inputs of energy, nutrients, and pollutants to the open lake are made directly to the inshore waters. These additions may cycle in the inshore waters, but eventually most find their way into the offshore waters, where they may be cycled less frequently or simply stored in bottom deposits in deep water. Smaller amounts of these energy and materials resources, when incorporated into fish, find their way back into coastal wetland, tributary, connecting channel, and terrestrial habitats as fish migrate inshore to spawn or as avian predators and humans ingest fish from the open lake.

2.2 Coastal Wetlands

In shallower water, a range of phenomena occur that are not possible in deeper water. Sunlight penetrating to the bottom makes possible the growth of rooted plants; and wave and wind energy are transformed by the lake bottom and shore, depositing sediments and causing erosion. Tributary flows change chemical and sediment concentrations and temperatures. The critical parameters determining the type of habitat are water depth, seasonal and long-term water level fluctuation, degree of exposure to wind and waves, substrate, and chemical and temperature regime. As a result of limited mixing and the variability of critical parameters, strong gradients exist over relatively short distances.

The boundary separating inshore from open-lake habitats lies where light ceases to penetrate significantly to the lake bottom. The depth at which this level of light extinction occurs varies tremendously between and within the lakes, but is usually less than 10 meters.

Of great interest within the inshore zone are wetlands, defined by the U.S. Fish and Wildlife Service (Cowardin et al, 1979) as:

> *"...lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For the purposes of this classification, wetlands must have one or more of the following attributes: (1) at least periodically, the land supports [aquatic plants]; (2) the substrate is predominately undrained hydric soil; or (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."*

An alternative definition has been developed by the U.S. Army Corps of Engineers for regulatory purposes (U.S. Army Corps of Engineers 1987).

Great Lakes wetlands differ from other Basin wetlands in that they are shaped by large lake processes, including waves, wind tides and especially long and short-term water level fluctuations. The fluctuating water levels result in a constant shifting of the communities in the wetland. Many have adapted to this constant fluctuation, and indeed require it to eliminate stronger competitors that thrive under more stable conditions.

Accordingly, Great Lakes wetlands can be classified based on how they are influenced by Great Lakes processes. The Lake Erie Water Level Study (International Lake Erie Regulation Study Board, 1981), identified the following seven wetland types.

<u>Open shoreline wetlands</u> usually exist as a fringe of aquatic plants adjacent to the shore. That fringe has expanded inland or lakeward in response to lake effects such as wave action and changes in lake levels. The dominant vegetation is usually emergent, but submergent plants can also be present and do not necessarily border on a shoreline. Examples of this wetland type are the north shore of the Inner Long Point Bay on Lake Erie and sections of the Detroit River shoreline in the vicinity of Fighting Island.

<u>Unrestricted bays</u> are characterized by a marshy fringe along a bay shoreline. These sites are afforded some protection from such lake effects as wave action. Depending on its size and depth, the whole bay could be vegetated. Submergent plants can be a part of those vegetative communities. This wetland type also includes typical open shoreline areas that are sheltered by an island or peninsula. Examples of this wetland type are the undiked section of the Ruhe Marsh of the Detroit River, and Black River Bay on Lake Ontario.

<u>Shallow sloping beach wetlands</u> are areas with very gentle to flat slopes on sand substrates. Very small variations in lake levels have had widespread effects on vegetation zones. Sand bars, if present, provide some wave protection. The large sand spit formations of Lake Erie (Long Point, Presque Isle, Point Pelee, and Pointe aux Pins) and Lake Michigan (such as Cecil Bay Marsh) constitute most of this wetland type.

<u>River deltas</u> are low islands and shallow zones formed by sedimentary deposits at a river mouth. The normally gentle slope allows the extensive shifting of vegetation zones when water levels fluctuate. The only wetlands identified as this type are the large St. Clair River delta along the northern edge of Lake St. Clair and the mouth of the Salmon River on eastern Lake Ontario.

<u>Restricted riverine wetlands</u> are characterized by marsh vegetation bordering a river course. The extent of the vegetated wetland is often restricted by a steep backslope on the landward side and the deeper water of the river channel on the other. The Grand River Marshes, the Portage River Marshes and the Sandusky River Marshes of Lake Erie are examples of restricted riverine wetlands.

<u>Lake-connected inland wetlands</u> are typified by the presence of a barrier beach or ridge that

restricts the outlet to the lake and also provides protection from wave action and other disturbances. Such wetlands can have a definite steep backslope or a gradual slope permitting some shifting of vegetation zones with changes in water regime. This type of wetland will have a connection to the lake, but a stream or groundwater discharge from its drainage basin could also contribute to its water supply. The Big Creek/Holiday Beach Marsh and Hillman Creek Marsh on Lake Erie, and Oshawa Second Marsh, Deer Creek Marsh and Sandy Creek Marsh on Lake Ontario are examples of this wetland type.

Protected (or Barrier beach) wetlands are separated from the lake by an unbroken natural barrier beach or ridge. The natural wetlands and some of the diked wetlands obtain their water from inland groundwater discharge, streams, and, at times, from the lake, when the wetland floods during storms. There is some seepage of water through dikes, which can be magnified by extremes in lake levels.

The diked, managed wetlands of the eastern Lake St. Clair and western Lake Erie shorelines and Cranberry Marsh, Port Bay, Beaver Creek and Red Creek Marshes on Lake Ontario are examples of protected wetlands.

Other inshore habitats
Outside of wetlands, there are a range of inshore habitats characterized by being permanently underwater. These include:

- Areas sheltered from wave and wind effects of the lake such as lagoons and embayments.
- Estuaries, which in addition to being sheltered from lake effects, are characterized by the flow of nutrients, organic matter and sediments from upstream. The temperature and chemical regime of water in estuaries also often differs from that of the lake.
- Areas where the lake bed gradient and/or the substrate change abruptly such as in shoals, reefs and trenches.

2.3 Shoreline

At the water's edge the Great Lakes provide a wide variety of habitats. Habitat type is determined by shoreline topography, substrate and geology, and by the operative forces of erosion and deposition in which the orientation to the prevailing wind can play a significant role.

Sand Dunes
Where onshore prevailing winds combine with the transport of sandy sediments in the lake, freshwater dunes occur. The dunes are uniquely associated with a number of communities including interdunal wetlands, jack pine barrens and sand beaches, and open dune communities varying in composition from north to south and east to west.

Lakeplains
Lakeplains occur where the ancestral Great Lakes occupied a different basin than those present today. Those former lakebeds are characterized by low topography with sandy, silty, or clay soils

and a high water table. The major topographic features are linear sandy beach ridges that were formed as the lakes receded in incremental stages. Around the southern Lakes, these areas supported extensive prairies and savannas, sand barrens, and coastal plain ponds (Nature Conservancy, 1994).

Although the lakeplains may extend some distance back from the shore, natural hydrological cycles associated with groundwater flow and lake level fluctuations play a key role in maintaining habitats for rare communities. They are also linked to the lakes in that they play an important (historical) role in floodwater retention both from precipitation and high lake levels; and function as ecological backstops during high lake levels when species and communities from the coastal wetlands may migrate inland to survive flooding (Nature Conservancy, 1994). They are also a significant source of fine materials that erode to the lakes in tributary floods and contribute to the sand and clay components of littoral drift.

Other typical shoreline habitats include emergent bars and spits, and beaches of cobble, gravel, and sand, bluffs and bedrock shores.

2.4 Tributaries

Tributaries contribute water, chemicals, organic materials and sediments, to the lakes and are habitat for anadromous species.

The range of tributary habitats depends upon the size, slope, substrate, geology and land-use in the drainage basin, groundwater characteristics, climate, and the nature of the terrestrial vegetation.

2.5 Connecting Channels

Connecting channels share characteristics of both tributaries and lakes. Like tributaries, they are flowing water habitats. Although flows in the St. Marys and St. Lawrence rivers are controlled, the cycle of water level fluctuations corresponds, more or less, to that of the upstream lakes; the amplitude of the fluctuations is less and high water is later in the summer than that of the tributaries. Their trophic status and planktonic communities largely reflect surface water conditions in the upstream lake.

The shallowness and current which characterize connecting channels result in earlier spring warming than in lakes. The current also promotes mixing, giving a more homogenous water quality and better oxygenation, although mixing, at least horizontally, is not always complete. For example, the Detroit River flows by Windsor half brown and half blue. Nevertheless, the comparatively warm, well-oxygenated currents carrying sediments and nutrients lead to significant biochemical activity, some improvement of water quality, and high productivity in shallow waters and wetlands in connecting channels, generally. The channels provide a broad diversity of habitats in close proximity to one another and include many of the habitat types found in the Great Lakes proper (Atkinson, unpublished).

2.6 Inland Habitats

Both wet and dry inland habitats of the Great Lakes play a significant role in the chemical and flow regime of the ground and surface water that eventually flows into the lakes. The quality of the vegetation communities determines the rate of erosion and thus the amount of sediments transported into the lakes. They also provide nesting sites for birds associated with lake communities (e.g. the bald eagle).

The climate of all inland habitat types in the region is affected by the Great Lakes themselves. Geomorphically, the most important historic factor in shaping habitat types was the glaciation.

The terrestrial habitats include a wide variety of forest types, most of which are sub-types of the northern mixed deciduous forest. Isolated prairies, savannas and sand barrens also occur in the Basin. The inland aquatic habitats include a wide variety of fens, as well as bogs, marshes, wet meadows and forested swamps, and a variety of pond and lake types.

3.0 Ecological Significance of Habitat Types

The fundamental importance of habitats comes from the fact that they are necessary for all life. For every species one or more specific habitats are necessary for its survival and reproduction. In this sense, habitat is a way of regarding the ecosystem from the perspective of one or more of the species that live in it. This section examines some of the important functions that habitats fulfill.

3.1 What's Important: Indicators of Significance

Habitat preservation and rehabilitation must take into account habitat functions and characteristics. Decisions about where to set priorities in habitat conservation, implicitly or explicitly, are based on some ranking or selection of these functions and characteristics.

The following functions and characteristics are discussed in this section:

- Role in nutrient cycling
- Productivity
- Influence on water quality and quantity
- Role in life cycle of species
- Biodiversity
- Indicator species

3.1.1 Role in Nutrient Cycling

Several nutrient-related functions need consideration when evaluating the role of different habitat types in the nutrient cycle. Neither the quantities of nutrients at each stage in the nutrient cycle nor the linkages between the various habitats are well known. Table 1 summarizes values based on professional judgement and tries to integrate both rates and area-weighted rates.

Table 1: The Nutrient Cycle in Great Lakes Habitats--summarizing values based on professional judgement and trying to integrate both rates and area-weighted rates.
Relative Importance: L=Low, M=Medium, H=High

Habitat types	**Nutrient Uptake**		**Nutrient Cycling**		**Nutrient Transfer**	
	From mineral substrate	Nitrogen fixation	Dissolved in water [uptake]	Organic matter [rate of decomposition]	to other habitats	to sinks
Open-Lake	L	L	L	L	L	H
Inshore including wetlands	H	H	H	H	L	H
Connecting channels	M	L	H	L	H	L
Tributaries	H	L	H	M	H	H
Shoreline	L	M	M	L	H	M
Inland habitats	H	H	L to H	H	H	M

Nutrient uptake

What quantity of new nutrients do each of the habitat types take up from the two primary sources - the mineral substrate and the air? In habitats with rooted plants - all but open-lake - some uptake of nutrients from the mineral substrate takes place. In terrestrial habitats, plant roots draw on the in situ geological substrate, while in the aquatic habitats the major source of mineral substrate nutrients are sediments brought by the action of water currents and waves. Sand dune communities also draw from sediments borne by the combination of water currents and wind. The uptake of nutrients from mineral substrate for each habitat type has not presently been quantified. Fixation of nitrogen from the air is limited primarily to terrestrial habitats, with the notable exception of certain algae, and rates are not known.

The transport of nutrients between habitats is not completely quantified. A major source of movement is water transport of organic matter and dissolved nutrients. Dissolved nutrients are taken up by phytoplankton and plants in the water. Their nutrient uptake is limited by plant distribution and abundance which in turn is limited by the availability of light. Again, comparative numbers are not available for the different habitat types.

The breakdown of organic matter - releasing nutrients for new life - proceeds at different rates in different habitats. In aquatic habitats, the limit is usually the oxygen content of the water. As a result, turbulent, well-oxygenated tributaries, connecting channels, and inshore areas exposed to breaking waves, can sustain higher turnover of organic matter. In Great Lakes terrestrial habitats, the turnover of organic matter is relatively slow. Definitive, comparative rates for different habitat types are not available, however Wetzel (1992) reported that wetlands occupy a very small portion of the drainage basins of the upper Great Lakes with deep, open pelagic waters. The regulatory influences of wetlands to nutrient loading and as a source of dissolved organic matter increase in the lower Great Lakes but are relatively small in comparison to those of smaller inland waters.

Several nutrient sinks operate in the Great Lakes basin:

- Transport out of the basin (e.g., via the St. Lawrence)
- Release into the air (for nitrogen)
- Storage in sediments (e.g., lake bottom)
- Storage in living biota
- Storage in detritus and other dead matter (e.g., peat bogs)

With more information on the dynamics of the nutrient cycle in the Great Lakes it would be possible to identify habitat types that make a major contribution to the nutrient cycle. Habitats that can absorb extreme fluctuations - especially an abundance of dissolved nutrients and dead organic matter - without suffering degradation (e.g. anoxic conditions in eutrophic lakes) are clearly performing an important function for the ecosystem. On the other hand, the natural condition, even now, in many Great Lakes habitats is usually one of nutrient limitation. Thus, the preservation of species able to extract nutrients from the substrate and water column, cycle nutrients rapidly or thrive under nutrient limitations, and the habitats that support them also becomes important.

3.1.2 Productivity

The primary productivity of Great Lakes habitats varies greatly. Highest productivity is found in the connecting channels (Atkinson, unpublished) and inshore habitat, especially in wetlands (Edwards et al. 1989). Table 2 summarizes current knowledge of biological energy production and transfer based on professional judgement and tries to integrate both rates and area-weighted rates.

Table 2: Energy Cycle in Great Lakes Habitats--summarizing values based on professional judgement and trying to integrate both rates and area-weighted rates.
Relative Importance: L=Low, M=Medium, H=High

Habitat types	Primary Productivity	Output of organic matter to other habitats	Input of organic matter from other habitats	Output of organic matter to sinks (e.g. peat bogs)
Open-Lake	L to M	L	M to H	L
Inshore including wetlands	H	M to H	M to H	M
Connecting channels	M	H	M	L to M
Inland habitats	M to H	L to M	M to H	H
Tributaries	M	H	M to H	L to M
Shoreline	M	L to M	L to M	L
Terrestrial	L to M	M to H	L	L to H

Materials and energy transfer occurs primarily through detritus carried by water currents and, within the open lake, by gravity. There is also some transfer via fish such as salmon, from open lakes and littoral zones into tributary streams. The extent of all such transfers has not been quantified.

Primary production is a measure of the growth of photosynthetic organisms, and represents the forage base serving as the foundation for all other species on higher tropic levels. Wetlands provide food for migrating birds, who use the local production to replenish their energy reserves for the next flight stage along their migratory route.

However, the conditions that limit productivity in many habitats (nutrients, oxygen, temperature, light) also create the niches to which species have adapted. Maximizing the productivity of all habitats (for instance through nutrient additions to oligotrophic systems) generally comes at the expense of overall species diversity. Recent reductions in the productivity of the lakes as a result of reduced human nutrient loadings have raised the question of what productivity goals to manage for (Nielson et al, 1993). One option is to simply manage to protect the natural species assemblage, letting them dictate the productivity goals.

From the point of view of habitat protection, highly productive habitats that serve as foraging places for species from other adjoining habitats are "local engines of growth" and might be considered priorities for protection. Coastal wetlands/marshes are principal examples of this.

Physical (Kinetic) Energy Conversion
Healthy habitats and their resident communities buffer, transform and use the kinetic energy of

the elements. In this function they protect the land from excessive erosion and the subsequent sedimentation elsewhere. Examples are trees anchoring the soil, streamside vegetation protecting the banks of tributaries and coastal wetlands buffering the effects of waves, wind, high water levels on the shore.

Some plant communities associated with habitat types even require these energy inputs for their survival. For instance, coastal wetlands require water level fluctuations in a range of periodicities to maintain their vigor and biological diversity.

The physical energy of the elements also results in the transport of sediments. Some habitat types are characterized by their reliance on continued sediment transport. Most notable are the coastal dunes where the primary dune communities depend on ongoing supply of new sand delivered by a combination of coastal currents and on-shore winds. Coastal wetlands also derive some of their nutrients and consequent vigor from sedimentation. For other habitats, such as rocky shoals or gravel beds in tributaries, sediments degrade the habitat for spawning fish. The continuing high levels of sedimentation as a result of human activities, would seem to put a premium on habitats that can incorporate sediments while retaining their vitality.

Again, no comparative figures are available on the amount of energy or sediments habitat types can absorb or deflect.

3.1.3 Influence on Water Quality and Quantity

Habitats influence water quality, water flows and levels, and ground water recharge.

The maintenance of water quality is a function of productivity and the ability of the biota to utilize nutrients and convert organic matter in any one habitat. Not surprisingly, inshore areas, connecting channels and especially wetlands are most effective in this role. However, their ability in this respect has limits, and exceeding these limits leads to degradation and a reduction in nutrient absorption capabilities. Figures on the range of capabilities and limits among habitat types are not currently available.

The removal of non-biodegradable toxic chemicals, such as heavy metals, proceeds via the incorporation of the toxic chemicals into organic matter and the subsequent storage or deposition of that matter where it is no longer available for living organisms. Alternatively, toxic chemicals may be deposited directly to lake and river bottoms with sediments. Sedimentation occurs where water currents become slower, such as where tributaries enter lakes or among the vegetation of wetlands. Neither of these two routes are particularly conducive to the long-term viability of the species or habitats accumulating the toxic chemicals. Nevertheless, habitats that function as contaminant sinks, do serve to moderate the immediate effects of toxic chemicals by removing them at least temporarily from circulation.

The role of inland habitats in maintaining water quality is perhaps overshadowed by their importance in regulating water flows and levels. From a basin-wide perspective, the inland habitats are the principal collectors of precipitation for the basin, and as such the ability of forests and wetlands to store and release water is critical to moderating tributary and groundwater flows to the lakes (Nature Conservancy, 1994). Inland habitats moderate tributary flows, reduce erosion and sedimentation associated with flooding, and thus moderate the seasonal and long-term fluctuations of lake levels.

3.1.4 Essential Habitats

Many animal species move between different habitats, with periods ranging from daily through seasonally to once or twice in their life cycle. In this way, habitats other than the one they are normally associated with, can play a critical role in the survival of the species, especially when normally dispersed populations concentrate in very small areas. In such a case, this habitat becomes far more important than what is suggested by the community of species that are more permanent residents. Examples of several different kinds of periodic use follow.

Migration stopovers
Historically, the marshes of the Detroit River, Lake St. Clair, Long Point and Western Lake Erie have been an important resting and feeding stop for the eastern population of canvasback duck, which winters on the Atlantic Coast. This population declined from 400,000 birds in the early 1950s to less than 147,000 by 1960 and has not recovered to its former levels.

The canvasback duck has rigid habitat requirements and behavioral traits that limit its adjustment to environmental change. It does not tolerate disturbance by boat traffic and depends strongly on wild celery. Densities of wild celery tubers decreased by 72% from eutrophication, sedimentation, carp, and pollution at two of five locations where ducks once fed between 1950 and 1985 (Schloesser and Manny, 1990; Kahl 1991).

Several authors have suggested that the decline in canvasback numbers is at least partially linked to the reduction in forage on their migration routes (Bellrose and Crompton, 1970; Mills et al., 1966; Trauger and Serie, 1974).

Spawning and nursery
Many of the fishes of the open lake move to the shallow waters or tributaries to spawn. In this respect, their needs are very specific - a certain kind of substrate, a certain amount of current, depth and temperature and within a narrow time-window. Often they return to the same places where they hatched. In a manner similar to waterfowl, during spawning a widely-dispersed population becomes concentrated in a habitat of relatively small size. For these populations, these spawning habitats become far more important than their relative size would suggest.

Nesting
While bald eagles have attracted attention, mostly because of the effects of toxic chemicals on their reproduction and development, it has also become apparent that reestablishing viable populations of eagles in the Great Lakes requires more than clean water. Nesting adult eagles use coniferous perches that are isolated from human disturbance (Bowerman and Giesy, 1991).

A survey of all the Great Lakes found that 34% of the coast is unsuitable as eagle nesting habitat (Bowerman, 1993). A separate study on Lake Erie found that bald eagles were already using most of the good to excellent sites, which make up only 12% of total potential sites. In this case, the sensitivity to disturbance and the large forage area require the protection of extensive coastal habitat, if bald eagles are to play more than an isolated and infrequent role in the ecosystem.

These three examples illustrate that species will use habitats in ways that do not conform to a habitat classification system, and that therefore the preservation of species such as the bald eagle needs the protection of a variety of habitats that do not at first glance appear to be linked.

Of special importance are habitats where a large part of the population gathers periodically in a limited area, more so when there do not appear to be alternative habitats to which these migrations may shift if the favored habitat becomes degraded.

3.1.5 Biodiversity

The diverse forms of animals and plants associated with different habitats have received much attention, and is a reason, along with primary productivity, given for habitat preservation (e.g. The Nature Conservancy, 1994). For purposes of evaluating habitats in this paper, two common measures of biological diversity have been separated for clarity's sake.

Richness

One measure of biodiversity is the number of species or unique community types found within habitat. A greater number of species, particularly endemic species, is generally an indicator of higher quality habitat. For example, as eutrophic and mesotrophic systems become degraded, species numbers decrease.

However, the degradation of coldwater oligotrophic systems, for example the addition of nutrients to Lake Superior, generally results in an increase in the total number of species (Tom Busiahn pers. comm.). Consequently, species richness cannot be used as an absolute indicator of habitat quality, in the same manner that higher productivity is not always a sign of higher quality habitat. This phenomenon complicates the interpretation of trend data and comparisons among habitat types.

Nevertheless, the comparative species richness of habitats does give some indication of their value in combination with other information about the habitat. Unfortunately, not enough data are available on species richness in the various habitat types to make meaningful comparisons.

Rarity

Rare and endangered species often have very specific habitat needs. The number of rare species depending on a particular habitat type is a further indicator of habitat significance. Preserving species and community richness at the global level requires priority protection for habitats that host globally rare species. At other levels of priority, it also means preserving the habitat of species that have become rare in the Great Lakes basin or in one or more of its subregions.

The U.S. Fish and Wildlife Service (1993) has compiled a list of 22 endangered and/or threatened species that are potentially affected by Great Lakes water quality. Another seventy-one species in the Great Lakes Watershed are candidates for designation as endangered or threatened species. A list of rare and imperiled elements compiled by the Nature Conservancy (1994) is especially useful because it shows what proportion of the rare and imperiled elements is found in each habitat type. The Conservancy cites the network of state and provincial natural heritage programs which have identified 131 elements within the Great Lakes basin that are critically imperiled (22), imperiled (30), or rare (79) on a global basis. Of these globally significant elements, 31 are natural ecological community types; the rest are individual species, subspecies or varieties including 49 plants, 21 insects, 12 mollusks, nine fish, five birds, three reptiles and one mammal. Additionally, 12 natural community types are recognized that, while not globally rare, form major components of the basin's landscape and support a wealth of biological diversity that is important to the basin's ecological integrity. The estimates of the proportion of globally rare species and communities found in various Great Lakes habitats is shown in Figure 1 (Nature Conservancy, 1994).

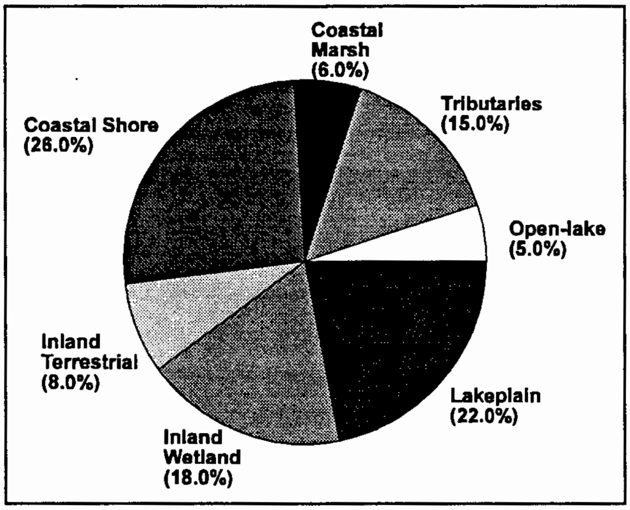


Figure 1: Estimated Proportion of Great Lakes-Unique Biodiversity Elements Found in Great Lakes Habitats

This figure shows the distribution of species and communities that are found either exclusively or primarily in the basin, or have their best representation in the Great Lakes Basin, among the ecological systems that support them. It confirms that the coastal systems (marshes, shores and lakeplains) contain a disproportionate amount of the unique biodiversity of the Great Lakes. Note that The Nature Conservancy's data tends to be weaker in wet environments compared to dry. Thus the biodiversity (and its significance) in Great Lakes aquatic, nearshore, shoreline, and wetland areas may actually be greater than that published in the report upon which Figure 1 was based.

In isolation, rarity as an indicator of habitat value leads eventually to a view of preservation as masking the value of representative species in creating and maintaining a healthy ecosystem. Thus, rarity too, is better combined with other indicators to give a rounded view of the comparative value of any particular habitat. Rarity, reflected in state/provincial Natural Heritage inventories, used as one data source among several, and cast in the context of a broader analytical process, helps protect productive ecosystems rather than just rare species.

3.1.6 Indicator Species

Healthy populations of diverse native species are one of the best indicators that habitats are of optimum quality. Accordingly, it may be simpler to monitor the health of selected indicator species rather than trading off difficult-to-compare criteria. By choosing a suite of species that require a broad range of high quality habitat types, it may be possible to read ecosystem health more accurately than measuring many attributes of different habitats in order to make comparisons that may be controversial. However, species populations are affected by other factors such as disease, predation and harvest, that are not directly linked to habitat quality. Thus, using a small number of species as "canaries" for the habitat needs of most or all species will still require some level of complementary data gathering on habitat quality. Impacts limited to subtle changes in the lower trophic levels (e.g. relative composition of zooplankton species) while the top trophic level is relatively unaffected could be harbingers of more profound changes later on. Programs like EPA's EMAP are trying to set up this sort of monitoring effort.

3.2 The Unique Role of Coastal Shore/Coastal Wetlands

Of all the habitat types, the coastal shore and the coastal marshes, rank most consistently high for all indicators of ecological and biological significance. The only exception would seem to be that it does not provide a home for a high percentage of the basin's globally rare species and communities (Nature Conservancy, 1994).

Although relatively small, the inshore zone concentrates much of the biological productivity and richness of the Great Lakes. The inshore zone plays a critical role in absorbing nutrients, organic matter and sediments, and through its high productivity removes some toxic chemicals. Coastal wetlands are uniquely adapted to and even require fluctuating water levels to maintain their vitality. Their productivity provides forage for many species from other habitats - animals from the land, including insects, reptiles, amphibians, mammals and migrating birds, as well as, sub-adult fish that subsequently migrate to the open lake.

The productivity and diversity of the inshore zone stem from the interaction of the water with land. In comparison to both the land and the open lake, the inshore zone has extra dimensions in determining the fine gradations of habitat type. Here both the nature and topography of the substrate, as well as the depth, flow, temperature etc., of the water determine the type of communities that establish themselves.

Besides the incoming solar radiation available equally in all habitat types, the inshore zone benefits from the energy inputs of water currents, wave and wind. These forces bring dissolved nutrients, sediments and organic matter in quantities sufficient to ensure that nutrients do not limit productivity to the same degree they do terrestrial communities. At the same time, the combination of currents, waves and solar radiation ensure good circulation and the resulting oxygenation. The greater warmth of inshore waters allows a higher metabolic rate and thus also contributes to overall productivity. Even when water and wind destroy the vegetation, this ultimately benefits the wetland by resetting succession and maintaining the highly productive, herb dominated system (Nature Conservancy, 1994). To the degree that connecting channels, and tributaries include a high proportion of shallow water inshore habitat, this discussion applies to them as well.

Having described the habitats of the Great Lakes, as well as their ecological and biological significance, it is now appropriate to examine their current status.

4.0 State of the Habitats

More than 200 years of European settlement have reduced the size and extent of many Great Lakes habitats and impaired the functional integrity of many that remain. The Great Lakes contain a mosaic of types and quality of habitat: a healthy habitat type in a given Lake can coexist with another that is not at all healthy, while the opposite situation may prevail in another Lake. Thus, habitat area figures, even when available, do not allow accurate comparisons of areal extent of habitat types, especially across jurisdictions. Conveying habitat status remains largely descriptive and anecdotal. This section describes the present state of the habitats as a whole and on a lake-by-lake basis.

4.1 Overall Quantity and Quality by Habitat Type

The ecosystem significance, quantity and quality of each habitat type has been summarized in Table 3. Similar tables have been prepared for each lake in the sections that follow.

All the tables show the main habitat types discussed in Section 2. Wetlands are included both under inshore, shoreline and inland habitats. The categories across the top of the table are explained as follows:

- **Ecosystem function** is a summary of relative role in nutrient cycling, of influence on water quantity and quality and of importance to life cycle of species.
- **Productivity** assesses the production by plant communities found in the habitat.
- **Rarity of Species and Communities** gives an indication of the number of globally rare species found in the habitat type.
- **Quantity** is a measure of the total area currently occupied by the habitat, relative to the average area occupied by all other habitat types.
- **Loss** is the amount of habitat that has been lost or fundamentally altered since the beginning of European settlement.
- **Quality** reflects the health of the remaining habitat.
- **Relative Significance** is the combined score of all the individual categories.

Scoring is on a five-part scale from low to high. For the overall Great Lakes score, each habitat is simply compared to all the other habitats to arrive at its relative ranking. For the individual lakes, each habitat is also compared with the same habitat in all the other lakes to arrive at a composite score.

Given the lack of knowledge about many of the parameters on which the scores are based, the potential for differences of opinion on individual scores is large. In other words, the scores are very much judgement calls. However, the usefulness of the exercise is fourfold:

- It gives relative overview of the status of the habitats and those which are most critical to the ecosystem.
- It provides a focus for discussion of the status and role of habitat types.
- It assists in identifying knowledge gaps.
- Its categories are one possible combination of criteria by which to rank habitats. As such it can serve as the basis for a discussion on how to set habitat preservation priorities.

The discussion on setting priorities can also examine the question of relative significance. The approach of the Nature Conservancy places greatest value on high-quality habitats supporting rare species and communities. While this approach has its merits, a case can be made for protecting high-quality habitats, which are still so extensive that their species have not become rare. It is also less difficult to protect and preserve than to replace lost habitat.

Table 3: Ecosystem Significance and Quality of Habitat in the Great Lakes--summarizing values based on professional judgement and trying to integrate both rates and area-weighted rates.

Habitat Type	Ecosystem Functions	Productivity	Rarity of Species / Communities	Quantity	%Loss	Quality	Relative Significance
Open-Lake	Moderate	Low	Low	High	Low	Moderate	(n/r)
Inshore	High	High	Very low	Low	High	Low	(n/r)
Shoreline	Low	Moderate	Very high	Low	Moderate	Moderate	(n/r)
Tributaries	High	Moderate	Low	Low	Moderate	Low	(n/r)
Connecting Channels	High	High	Low	Very low	High	Low	(n/r)
Inland	Moderate	Moderate	Moderate	Moderate	High	Moderate	(n/r)

(n/r indicates no responses from reviewers)

Open-Lake

While the open-lake habitat has remained virtually unchanged in size, its quality has been impaired. Nutrient concentrations in the lower Lakes have been reduced from their highs of the 1960s and 1970s. As a result growth rates of nuisance algae have also been reduced. However, agreement on ideal long-term nutrient levels has not been reached (Nielson et al., 1993). Locally, such as in many Areas of Concern, nutrient levels are still too high, leading to oxygen depletion and impaired fauna. ("Areas of Concern" are the 43 Great Lakes toxic "hotspots" identified by the U.S. and Canadian governments based upon the recommendations of the International Joint Commission).

The presence of toxic chemicals in the water continues to affect the health of fish and bird predator populations (LEP, 1994). Basin-wide data on the effect of siltation, especially as it degrades spawning and benthic habitat in the open lake are not available.

Biological sources of degradation are overfishing and the introduction of non-native species, such as the zebra mussel which have out-competed endemic filter feeders and altered the substrate and water clarity especially of parts of Lake Erie. Koonce (1994) argues that stresses associated with biological factors have, in fact, caused more severe degradation than physical and chemical stresses in the lake ecosystems. Several of the endemic fishes -- formerly dominant species -- have been eliminated, and others, such as the shortnose ciscoe and the globally rare lake sturgeon, now have severely restricted distributions. Although portions of the lakes appear to support high-quality benthic communities, the overall documentation of the character and quality of invertebrate biota is still scanty. The Lakes' biotic communities also have not been systematically described or ranked from a biodiversity standpoint. However, they would presumably rank as globally rare to imperiled, due to restricted distribution, high level of threat, ecological fragility, widespread damage and because they are the single largest source of freshwater in the world (Nature Conservancy, 1994).

Inshore

Throughout the Great Lakes basin, the picture for wetlands is clear: most of the pre-settlement wetlands, both inshore and inland, have been lost. While the rate of loss has slowed in recent decades, there is still a net ongoing loss in the quantity and quality of wetlands habitat.

Other inshore habitats have also suffered. Quantitative losses occurred primarily through lakefill and dredging in urban areas. Qualitative losses have been more extensive and include sedimentation of spawning grounds, eutrophication, toxic chemicals in the water, changes in the thermal regime and invading of exotic species. Basin-wide data are not available.

Inland and coastal wetland losses in the eight States at least partially within the Great Lakes Basin have been disproportionately greater than in many other U.S. regions. Since the 1780s, Great Lakes Basin States have lost an estimated 34.9 million (59.7%) acres of wetlands out of its 58.6 million original wetland acres. This compares with an average loss of 52.8% nationwide. There are an estimated 23.6 million acres of wetland remaining in the eight Great Lakes States, representing more than 22% of the wetlands within the lower 48 states (Dahl, 1990). In Ontario south of the Precambrian shield, wetlands once covered an estimated 25% of the landscape. The total losses in southern Ontario are estimated at 80% (Patterson, 1994). Recent historic losses of wetlands in the Great Lakes basin have been estimated to be 20,000 acres/year (Great Lakes Basin Commission 1981). The data are insufficient to estimate the current rate of loss.

Coastal wetland loss estimates from different sources have been compiled for various sections of the Great Lakes by Bedford (1990). She reports no estimates were found for Lakes Superior and Huron, but 11 to 100% of the wetlands have been lost in sections of the other three Lakes and Lake St. Clair.

Compilation of various reports, primarily the Lake Erie Water Level Study (International Lake Erie Regulation Study Board 1981) and Herdendorf et al. (1981), indicate an approximate total of 120,000 hectares of coastal wetlands along the U.S. shoreline of the Great Lakes. Table 4 gives a breakdown of U.S. wetland area on each lake, indicating that on the U.S. side, the most wetland can be found in Lake Michigan. On the Canadian side no comparable data exist for all the lakes, but Whillans et al (1992) report approximately 25,000 ha of shoreline wetlands on the Canadian portion of Lake Ontario.

WETLAND	%
Lake Ontario-St. Lawrence	6.9
Whitefish Bay	3.6
St. Mary's River	4.4
Lake Erie-Niagara	6.7
St. Clair-Detroit	3.2
Lake Superior	14.5
Lake Michigan	40.4
Lake Huron	20.4

Table 4. Distribution of the approximately 300,000 acres of coastal Great Lakes wetlands in the U.S. (Sources: Herdendorf et al. 1981 and others). No comparable Canadian data exist.

Wetland degradation results from numerous human activities. Other than direct filling of wetlands, the most frequently encountered changes are:

- sedimentation which lowers penetration of sunlight and displaces some fish species;
- loss of hydrological connectivity both to the lake and to tributaries/groundwater;
- loss of refugia to which communities can shift during periods of high and low water levels;
- reduced lake level fluctuations will become a major future source of degradation if management scenarios are implemented;
- discharges of pollutants and contaminants which are an immediate stress on water quality and secondly on biological functions; and
- non-consumptive use disturbance which may affect sensitive species.

Often wetlands are subject to numerous concurrent stresses. Herdendorf et al. (1986) note that the loss of coastal wetlands along the Michigan side of Lake St. Clair has resulted in a loss of wetland functions and values. For example, public drains installed to improve runoff now occupy former creek channels, which no longer benefit from the flood water storage, sediment trapping, and nutrient uptake afforded by the natural wetlands. Nor do the remaining wetlands along the river mouth and shorelines which have been reduced in size, partially developed (especially on the lakeward side) and otherwise impacted, have the fish and wildlife value they once had.

Shoreline

The encroachment on shoreline habitats results from agricultural, recreational, urban and industrial development. Almost half the globally rare species and communities in the basin fall into Nature Conservancy's (1994) coastal shore and lakeplain types, which correspond generally to the shoreline category used here. For instance, sand dunes provide habitat for a range of state and federal threatened and endangered species including piping plover, Pitcher's thistle, Lake Huron tansy, Houghton's goldenrod, and many others (Cwikiel, pers. communication). On the former lakeplains, the remnant wet prairies and wet meadows are themselves rare and provide habitat to a high percentage of endangered species (Cwikiel, pers. communication).

Table 5 shows Bowerman's (1993) estimates of the quality of bald eagle nesting habitat within 1.6 km of the shore for each of the Lakes. He estimates that 34% of the coast is unsuitable nesting habitat for bald eagles. No similar Basin-wide surveys of the quality of shoreline habitat for other species exist. The Nature Conservancy (1994) reports that the extensive dunes on Lake Michigan's eastern shore are largely intact, and the coasts of Lakes Superior and Huron remain sparsely settled. Basin-wide data on the general condition of shoreline habitats are not available.

Table 5 Shoreline (km) by habitat classification for Bald Eagles on each Great Lake. (after Bowerman, 1993)

Lake	Good km (%)	Marginal km (%)	Unsuitable km (%)	Total km (%)
Superior	2186 (76.5)	186 (6.5)	487 (17.0)	2859 (27.0)
Michigan	624 (32.5)	353 (18.4)	942 (49.1)	1919 (18.1)
Huron	1975 (65.0)	319 (10.5)	744 (24.5)	3038 (28.7)
Erie	94 (7.0)	543 (40.4)	707 (52.6)	1344 (12.7)
Ontario	112 (7.8)	614 (42.8)	710 (49.4)	1436 (13.5)
TOTAL	4991 (47.1)	2015 (19.0)	3590 (33.9)	10596

Tributaries
While loss of tributary habitat is mostly limited to urban areas, quality impairment has been significant. Impacts have been felt on a wide range: channelization, dredging, damming, sedimentation, loss of bankside vegetation, eutrophication, increased spring flooding, and toxic contamination. Large areas of inland forests and wetlands that once served to regulate the quantity and quality of water flowing into tributaries have been lost. As a result, tributaries pass on their pollutant and sediment loads to the lakes and their suitability as spawning habitat has been seriously impaired.

Connecting Channels
The connecting channels have suffered from the same pressures as the inshore habitat, only more so. Large wetland areas have been lost to agriculture. Urban and shipping needs have led to infilling, channelization and the building of bulkheads, and a loss of other inshore and channel bottom habitats. Toxic contaminants have accumulated in sediments and continue to effect species directly and indirectly. Despite the losses and impairments, some of the basin's most extensive and productive wetlands and inshore habitats survive in the connecting channels. A channel-by-channel description of the state of connecting channels follows below.

Inland
Inland habitats have been extensively altered, primarily through deforestation and wetland

drainage for agriculture. Inland wetland losses were included in the figures cited above. Habitat quality has been impaired by the effects of air pollution on forests, and discharge of wastes into tributaries that flow through inland wetlands.

4.2 Lake Superior

The dominant habitat of Lake Superior is the very large, deep and oligotrophic open lake. Steep shorelines, and the deep lake have created little room for extensive inshore shallows. However, many of the Lake's tributaries have extended deep-water estuaries or extensive shallows off their mouths, offering excellent shallow-water habitat (Lawrie, 1978). Nutrient input from the tributaries is low, and so is the primary productivity of the lake (Iwachewski, 1994). Shorelines vary from steep rock cliffs through low-lying clay and gravel bluffs, to sheltered embayments and wetlands. The inland habitats are divided into seven ecoregions, the northern and eastern areas dominated by fir spruce and the southern and western covered by maple, aspen and conifer mixed forest (LSBP, 1993).

Habitat loss and impairment have resulted from industrial operations, forestry and mining activities, sewage disposal, road and railway construction, and deposition of airborne contaminants, much of it from outside of the basin (Busiahn, 1990). Lawrie (1978) reports that many shallow-water benthic environments were ruinously affected by the deposition of sawdust and other woody, allochthonous materials, because of logging in the late 19th and early 20th centuries. The recent discovery of algal mats covering several isolated rock shoals (Edsall et al., 1991) suggests that current human activities are continuing to have an impact on spawning habitat. Log drives and stream channelization resulted in riverine habitat loss across the north shore (LSBP, 1993). Hydroelectric development has resulted in habitat loss and degradation from fluctuations in water levels and blockage of traditional migratory routes by dams on several rivers. The Nipigon River is perhaps the worst example of this (LSBP, 1993).

Lake Superior has the highest water quality of all the Great Lakes. The trend shown over the last 60 years of water chemistry data for Lake Superior is best described as stable, in contrast to the recent changes in lakes Erie and Ontario. One of the major concerns is atmospheric deposition, which accounts for about 90% of some toxic chemicals entering the Lake. In seven Areas of Concern, water and habitat quality have been locally impaired, resulting in problems such as a loss of wetlands, contaminated sediments, degraded benthic communities and restrictions on fish consumption. In the four Canadian AOCs, one of the primary sources of degradation has been pulp and paper mills (Iwachewski, 1994).

While Lake Superior as a whole is in relatively good condition, some inshore and tributary habitats have been degraded to the point where open-lake populations have been affected. Table 6 gives an overview of the ecosystem significance and the state of the habitats for Lake Superior. An explanation of the ranking criteria and scoring is found in Section 4.1, Overall Quantity and Quality by Habitat Type.

Table 6: Ecosystem Significance and Quality of Habitat in Lake Superior--summarizing values based on professional judgement and trying to integrate both rates and area-weighted rates.

Habitat Type	Ecosystem Functions	Productivity	Rarity of Species / Communities	Quantity	Loss	Quality	Relative Significance
Open-Lake	low	very low	moderate	very high	very low	very high	(n/r)
Inshore	high	moderate	moderate	low	moderate	high	(n/r)
Shoreline	low	low	moderate	very high	low	high	(n/r)
Tributaries	high	moderate	moderate	low	moderate	moderate	(n/r)
Inland	moderate	low	moderate	high	low	moderate	(n/r)

(n/r indicates no responses from reviewers)

4.3 Lake Michigan

One of the most impressive natural shore types of the entire Great Lakes is the long expanse of sand dunes along the eastern shore of Lake Michigan. The western and northern shores are characterized by erodible bluffs and non-erodible rocky shores respectively.

The inshore zone contains extensive wetlands - about 40% of the total in the United States Great Lakes (Herdendorf et al., 1981). The inshore waters of the lake are generally mesotrophic.

Given the Lake's long north-south axis, climate plays a role in determining the community composition of the various habitats. The north-south gradation is pronounced enough that northern Lake Michigan is often grouped with Lake Superior to the Upper Lakes, while the southern end of the Lake has more similarities with Lakes Erie and Ontario.

This north-south gradation carries over to the impairment and loss of habitat. The south, with its concentration of agriculture and urban areas, has generally higher levels of nutrients (over 20 μg/l of phosphorous in some areas) and toxic chemicals than the north. Development in the south has also led to a greater loss of inshore and shoreline habitat than in the north. In the north, Green Bay has been impacted most seriously, with high nutrient and PCB levels, and public health advisories against consumption of several species in addition to the lakewide advisory for large trout and salmon. Lakewide, degradation of water quality from land use activities and waste discharge has affected fish spawning in certain areas. Surface waters in Lake Michigan have higher burdens of heavy metals than any of the other Great Lakes. Table 7 gives an overview of the ecosystem significance and the state of the habitats for Lake Michigan. An explanation of the ranking criteria and scoring is found in Section 4.1, Overall Quantity and Quality by Habitat Type.

Table 7: Ecosystem Significance and Quality of Habitat in Lake Michigan--summarizing values based on professional judgement and trying to integrate both rates and area-weighted rates.

Habitat Type	Ecosystem Functions	Productivity	Rarity of Species / Communities	Quantity	Loss	Quality	Relative Significance
Open-Lake	low	moderate	(n/r)	high	very low	moderate	(n/r)
Inshore	high	high	(n/r)	very high	moderate	moderate	(n/r)
Shoreline	low	low	(n/r)	high	moderate	high	(n/r)
Tributaries	moderate	high	(n/r)	moderate	(n/r)	low	(n/r)
Inland	high	moderate	(n/r)	high	moderate	moderate	(n/r)

(n/r indicates no responses from reviewers)

4.4 Lake Huron

The diverse shoreline of Lake Huron is the longest of the Great Lakes, its length extended by the shores of its numerous islands. Rocky shores associated with the Precambrian shield cover the northern and eastern shores, limestone dominates the shores of Manitoulin island and the northern shore of the Bruce Peninsula, and glacial deposits of sand, gravel, and till predominate in the western, southern, and south-eastern portions of the shore. Shoreline and inshore habitats are correspondingly diverse.

Inshore habitat includes extensive local concentrations of wetlands primarily in sheltered bays and river mouths, totalling about 24,400 ha on the United States side (Herdendorf et al, 1981 and others) and, based on an incomplete survey, at least 12,000 ha on the Canadian side (Liskauskas, 1994). Saginaw Bay, the DeTour/Drummond Island/Les Cheneaux Islands areas and Severn Sound have especially large wetland areas. Matchedash Bay is a Class 1 provincially significant wetland. Other inshore habitat is less well-documented on a lakewide basis. The open lake is oligo-mesotrophic, its nutrient load lying between that of Lakes Superior and Michigan (Liskauskas, 1994).

Lake Huron has more islands than any other lake in the world, including Manitoulin Island, the world's largest in freshwater. Manitoulin has more than 70 large lakes that can be grouped into eight habitat types based on fish species composition.

Neither descriptions nor data on the quantity and quality of inland habitats were available. Little information on habitat characteristics of tributaries is available. On the Canadian side, the Severn watershed is characterized by extensive wetlands, while the lower reach of the Spanish River is an area of deep even flow, with some abundance of aquatic plants in the estuary. Both of these rivers are receiving intensive study.

Habitat loss and degradation have not been systematically documented except locally. In Saginaw Bay, waste discharges and waste heat from power plants have reduced fish habitat. Phosphorus concentrations exceed 20 µg per litre and are some of the highest values reported in the Great Lakes. Eutrophication has also affected habitat in Severn Sound, Collingwood and Spanish Harbours. In the latter two, sediment contamination and dredging have contributed to habitat impairment. In the Spanish River, fluctuations in water levels, shoreline alterations and deposition of bark and fibre are cited as sources of habitat degradation (Liskauskas, 1994).

In comparison to Lakes Michigan, Erie and Ontario, contaminant concentrations in Lake Huron are low. Only Lake Superior waters are lower in heavy metal concentrations. Nevertheless, public health advisories exist regarding the consumption of trout from the open lake and all four Areas of Concern. Table 8 gives an overview of the ecosystem significance and the state of the habitats for Lake Huron. An explanation of the ranking criteria and scoring is found in Section 4.1, Overall Quantity and Quality by Habitat Type.

Table 8: Ecosystem Significance and Quality of Habitat in Lake Huron--summarizing values based on professional judgement and trying to integrate both rates and area-weighted rates.

Habitat Type	Ecosystem Functions	Productivity	Rarity of Species / Communities	Quantity	Loss	Quality	Relative Significance
Open-Lake	low	low	(n/r)	high	very low	high	(n/r)
Inshore	high	moderate	(n/r)	very high	moderate	high	(n/r)
Shoreline	moderate	low	(n/r)	very high	low	high	(n/r)
Tributaries	moderate	moderate	(n/r)	moderate	moderate	moderate	(n/r)
Inland	low	moderate	(n/r)	moderate	moderate	moderate	(n/r)

(n/r indicates no responses from reviewers)

4.5 Lake Erie

Lake Erie is made up of three relatively distinct basins: the shallow western basin, and the deeper central and eastern basins which are separated by a sill. The entire depth of the western basin is stirred by wind action, resuspending bottom sediments for filter feeders in the water column and preventing any lengthy thermal stratification. Historically, benthos has been dominant in the basin, feeding on the organic load delivered by the Detroit and Maumee rivers. The basin also provides spawning shoals for fish from the other basins. The central and eastern basins have lower flushing rates and greater thermal stratification than the western basin. Even before human intervention, the central basin seems to have had periods of anoxia (LEP, 1994).

Much of the Lake Erie shore is composed of limited beach area at the foot of bluffs that are composed of silty-clay soils. The loss/degradation of coastal wetlands exacerbates the "stirring" effect on the clay soils. Erosion of this material results in turbid or milky-colored inshore waters. In contrast to the inshore conditions, the water is much more transparent offshore. In the central and eastern basin, the offshore water transparency is typical of oligotrophic conditions. The wind-fetch in the central basin causes strong along-shore currents and undertows that move sediment from the bluffs along the shore, building peninsulas (Pelee, Point-aux-Pins, Long Point, Presquile). The turbidity and shifting of unstable substrates are factors that limit primary and secondary production in the inshore habitat. Elsewhere in the lake, primary production and loading of detrital organic material to the littoral zone supports high levels of secondary production by benthic insects, crustaceans, molluscs and gastropods. The peninsulas shelter significant remaining wetlands and create bays that provide spawning and nursery habitat for several fish species (LEP, 1994).

Lake Erie once had very extensive wetlands, especially on the U.S. side, including the 4000 km^2 Black Swamp at the Maumee River which has been reduced to 100km^2. Significant wetlands on the Canadian side occur at Dunnville, Rondeau Bay, Long Point Bay and Point Pelee. While conversion, primarily by agriculture continues, a more widespread problem for wetlands are agricultural nutrients and sediments. High turbidity prevents the establishment of submergent vegetation and shifts the fish community from predator to bottom feeder dominance (LEP, 1994).

There are comparatively few areas of rock littoral substrate. Virtually all such habitat has been encrusted with zebra and quagga mussels, except for areas where waterfowl or fish predation and ice scour limits mussels to the sheltered sides of rocks. Quagga mussels predominate in the east, while zebra mussels predominate in the central and western basins. The filtering action of the mussels has resulted in increased water transparency both inshore and offshore. The fecal pellets produced by the mussels have provided detrital material to support production of amphipods and other benthic organisms (LEP, 1994).

Rocky substrates have also been degraded by algal growth and sedimentation, both of which limit spawning. In the Detroit River, contaminated sediments are thought to be affecting fish eggs. On the Grand River, dams have limited the upstream migration of walleye.

Over past decades, Lake Erie has suffered from eutrophication, which decimated the benthic communities of the western and central basins. Although phosphorus loadings have been reduced below target levels, benthos of the western basin has not recovered, perhaps due to some combination of oil in the sediments, pesticides and fish predation. In the central basin, the oxygen demand of the substrate layer has not decreased despite the lower nutrient levels. The new oligotrophic conditions have led to a decline in the productivity of percid fishes.

Table 9 gives an overview of the ecosystem significance and the state of the habitats for Lake Erie. An explanation of the ranking criteria and scoring is found in Section 4.1, Overall Quantity and Quality by Habitat Type.

Table 9: Ecosystem Significance and Quality of Habitat in Lake Erie--summarizing values based on professional judgement and trying to integrate both rates and area-weighted rates.

Habitat Type	Ecosystem Functions	Productivity	Rarity of Species / Communities	Quantity	Loss	Quality	Relative Significance
Open-Lake	high	high	(n/r)	high	very low	low	(n/r)
Inshore	high	moderate	(n/r)	moderate	very high	low	(n/r)
Shoreline	low	moderate	(n/r)	moderate	high	low	(n/r)
Tributaries	high	high	(n/r)	moderate	moderate	low	(n/r)
Inland	moderate	moderate	(n/r)	moderate	high	moderate	(n/r)

(n/r indicates no responses from reviewers)

4.6 Lake Ontario

Although Lake Ontario is the smallest of the Great Lakes, it has the largest drainage basin relative to its size of all the Great Lakes, and is second only to Lake Superior in terms of depth relative to size. The bottom topography of the lake is relatively smooth with the exception of a sill which separates the Kingston Basin from the remainder of the lake. This separation results in unique water quality characteristics in the Kingston Basin (Kerr and LeTendre, 1991).

Eighty-five percent of the lake perimeter is characterized by regular (nearly linear) shorelines sloping rapidly into deep water (Whillans, 1980). This shoreline configuration tends to lead to a relatively low biological productivity (Ryder, 1965). Whillans et al (1992) cite a total coastal wetland area of 32,422 ha for the lake. In the majority of the lake (excluding the Kingston Basin) the nearshore zone (0 to 10m depth) is found in a narrow 0.5 to 1.5 km wide band. This represents only 7% of the total surface area. The substrate of the inshore zone consists of extensive glacial sediment and bedrock overlaid with relatively small, discrete deposits of post-glacial sediment. Most of this zone is unsuitable for rooted aquatic plants because of exposure to wave action and large-scale shifts in sediments during storm events (Whillans, 1980). The notable exceptions to this are Hamilton Harbour, Toronto Waterfront, Oshawa Second Marsh, Presqu'isle Bay/Wellers Bay, East Lake, West Lake, Ironduquiot Bay, Sodus Bay, and extensive wetland systems on the east side of Lake Ontario which are all sheltered by barrier beaches or islands. Lake Ontario's wetlands are not extensive, and most are either in these sheltered bays or at other river mouths (Mathers, 1994).

In contrast, the shoreline in the Kingston Basin is highly irregular and the nearshore zone (0 to 10m depth) represents 31 per cent of the basin's surface area. The largest areas of shallow water in the Kingston Basin include the Bay of Quinte, Chaumont Bay, Henderson Bay, and Prince Edward Bay. The sheltered nearshore zones in all areas of the lake tend to support aquatic rooted plants and relatively diverse warm-water aquatic communities. The substrate from

Wellington to Kingston is generally bedrock (80%) with occasional deposits of fines in protected areas (Balesic, 1979).

The shoreline substrates are similar to those of the inshore zone with occasional rock outcrops. The eastern basin is characterized by bedrock shores. For the most part, the glacial sediments form bluffs of various heights, interspersed with beaches. Sand dunes are present at only two locations.

The tributaries of Lake Ontario drain glaciated sediments that were once covered with mixed hardwood forests. With its large drainage area relative to its size, Lake Ontario's tributaries play a greater role in transporting nutrients and sediments than they do for other lakes.

The status of the physical habitat is difficult to assess since little historical data is available. However, several specific examples of habitat degradation are known. Areas where fractured bedrock and glacial drift are swept clean of fine materials were historically used as spawning sites for several offshore fish species including lake whitefish, lake herring, and lake trout (Whillans, 1980). Much of the nearshore habitat in the Toronto area has been destroyed by mining for construction aggregate and filling or armoring of the shoreline. This has occurred in the rest of the lake, primarily where urbanization has occurred along the shoreline. Agricultural land-clearing was widespread in the Lake Ontario watershed during the early nineteenth century. This led to extensive soil erosion and siltation of stream and nearshore spawning grounds. Several of the fish species, including lake sturgeon, Atlantic salmon and walleye, which historically inhabited Lake Ontario migrated up streams to spawn. Numerous dams for saw and grist mills were constructed blocking upstream migrations of fish (Bridger and Oster, 1981) and contributed to the decline of these important fish populations.

Lakewide data on the loss of Lake Ontario wetlands are not available, but Whillans (1982) suggested that losses could be as high as 75% in areas of intensive settlement.

Eutrophication has been one of the most obvious forms of degradation of the aquatic habitat of Lake Ontario in the past (Christie, 1972). In particular, the water quality of most of the sheltered nearshore zones has been strongly affected by cultural eutrophication since the 1940's and possibly earlier. Nuisance algae blooms have resulted in decreased water clarity and reduced the abundance of beds of rooted aquatic plants in many sheltered nearshore zones, such as the Bay of Quinte. Consequently, there has been a decline in the abundance of piscivorous fish species associated with weed beds such as largemouth bass and northern pike (Hurley and Christie, 1977). Despite water quality improvements in many inshore zones such as the Bay of Quinte, clear waters, rooted aquatic plants, and a diverse fish community have not returned to most of these areas.

The signs of eutrophication of the open lake and exposed nearshore zones are not as obvious as in the sheltered nearshore zones. One specific example is the spawning beds in the exposed nearshore zones which have been degraded by dense mats of Cladaphora, a nuisance algal typical of eutrophic systems (Whillans, 1980).

Reduced nutrient input during the past decade seems to be shifting the lake towards a more oligotrophic state (Anonymous, 1992). The algal community composition has changed throughout the lake, with an 18% reduction in the annual rate of photosynthesis in the 1980's. Zooplankton production is thought to be 50% lower. Lower production is expected to have ramifications for the entire food chain, including predatory fish (Mathers, 1994).

Toxic chemicals have also impaired habitat quality. Public health advisories restrict the consumption of trout and salmon from the lake. Contaminants have found their way into sediments. In general, harbour and river mouth sediments, which are often also productive wetlands and spawning grounds, have higher contaminant concentrations than do nearshore and open-lake sediments. Seven sites, containing heavily contaminated sediments, have been identified and designated as Areas of Concern.

Warm water outflows from hydroelectric generation plants, and deepwater cooling proposals have the potential to influence the thermal regime of the lake. The physical impacts of deepwater cooling at the scale currently proposed are thought to be small (Boyce et al., 1993). Table 10 gives an overview of the ecosystem significance and the state of the habitats for Lake Ontario. An explanation of the ranking criteria and scoring is found in Section 4.1, Overall Quantity and Quality by Habitat Type.

Table 10: Ecosystem Significance and Quality of Habitat in Lake Ontario--summarizing values based on professional judgement and trying to integrate both rates and area-weighted rates.

Habitat Type	Ecosystem Functions	Productivity	Rarity of Species / Communities	Quantity	Loss	Quality	Relative Signifi-cance
Open-Lake	moderate	moderate	(n/r)	high	very low	moderate	(n/r)
Inshore	very high	moderate	(n/r)	low	high	moderate	(n/r)
Shoreline	low	moderate	(n/r)	moderate	high	moderate	(n/r)
Tributaries	high	high	(n/r)	high		poor	(n/r)
Inland	moderate	moderate	(n/r)	high	high	poor	(n/r)

(n/r indicates no responses from reviewers)

4.7 Connecting Channels

In the connecting channels, the proximity of the opposing inshore zones to one another gives a greater diversity of habitats within a given area than is generally the case in the lakes. The upper three channels are characterized by low shorelines and gradients (see Table 11) that favor the development of extensive wetlands. In the Niagara and St. Lawrence river wetlands are proportionately less important. The trophic status and planktonic communities usually mirror the upstream lake, however, local habitat conditions may vary widely from conditions found in the channels.

Table 11: Physical Characteristics of Great Lakes Connecting Channels

Channel (river)	Length (km)	Gradient (m/km)	Average Flow (CMS)
St. Mary's	97	0.075	2,100
St. Clair	43	0.056	5,300
Detroit	51	0.018	5,400
Niagara	56	1.77	5,700
St. Lawrence	842	0.088	6,700

The connecting channels are often the areas most heavily utilized by humans. It follows that habitat in all five connecting channels has been impaired. An indication of the degree of impairment is the designation of part or all of each connecting channel as an Area of Concern. In addition to the impacts of agriculture, industry and urbanization which affect the lakes, the connecting channels suffer from physical alterations for shipping, water level management and power generation. The natural features and major impacts for each connecting channel are summarized below.

St. Mary's River

Extensive areas of emergent marsh wetland border the lower river. Eighty-three percent of the land within five km of the river consists of natural forest and wetland (Atkinson, 1994). An abundance of diverse fish habitats may explain the large number of species (74) found in the river (Liskauskas, 1994).

Major loss of fish habitat has occurred through the extensive alterations and dewatering of the St. Mary's rapids. Further habitat loss is concentrated in the northern section of the river, by Sault St. Marie, where extensive wetland and further fish habitat have been lost to dredging, filling and shoreline development (Krishka, 1989). Contaminated sediments are concentrated in the north, and disturbances from shipping negatively affect sediments and inshore habitat.

St. Clair River

The St. Clair is still characterized by its extensive wetlands, most of which lie in the largest freshwater delta on the earth, where the river enters Lake St. Clair. A total of 4,000 hectares of emergent aquatic plants are distributed over 15 wetlands. The area is a very important staging area for migrating birds and fish.

The remaining wetlands represent as little as 30% of what once existed. Drainage for agriculture has accounted for 92% of these losses (Atkinson, 1994). Extensive bulkheading and infilling have resulted in the loss of spawning, nursery and feeding sites for fish.

Detroit River
Excellent fish and wildlife habitat in the lower river includes more than 31 wetlands covering 2000 hectares. About 90% of the original wetlands have been lost (LEP, 1994).

The river is heavily urbanized and industrialized with 86% of the U.S. shoreline occupied by retaining walls and harbour structures. The dredging, bulkheading and or backfilling of wetlands, inshore waters, bayous and embayments have resulted in extensive losses of spawning and nursery areas for fish and wildlife.

Niagara River
The Niagara shoreline is composed of low banks in the upper portion of the river and a deep gorge cut through sedimentary deposits in the lower river below the Falls. The river and its tributaries drain wetlands covering almost 5,000 hectares (Atkinson, 1994).

Both sides of the river are intensively used for urban and agricultural purposes. Extensive filling has occurred in the Buffalo area. Other impairments stem from erosion/sedimentation, removal of vegetation, human intrusion, toxic materials and disruptions in flow characteristics (Atkinson, 1994).

St. Lawrence River
Initially, the St. Lawrence River flows over bedrock. Many small islands dot the upper reach. At Cornwall, the substrate changes to clay with low shores of glacial sediments, primarily clay. Here significant wetlands occur, for example, the two in Lake St. Francis which cover 1,500 hectares.

The single biggest impact on fish and wildlife habitat have been the five dams between Kingston and Montréal. Below Montréal, that City's waste discharges also play a role in making the river inhospitable for some species. Along the entire river shoreline, modifications and nutrient enrichment affect fish spawning and nursery areas (Atkinson, 1994). Table 12 gives an overview of the ecosystem significance and the state of the habitats of the connecting channels. An explanation of the ranking criteria and scoring is found in Section 4.1, Overall Quantity and Quality by Habitat Type.

Table 12: Ecosystem Significance and Quality of Habitat in the Connecting Channels--summarizing values based on professional judgement and trying to integrate both rates and area-weighted rates.

Habitat Type	Ecosystem Functions	Productivity	Rarity of Species / Communities	Quantity	Loss	Quality	Relative Significance
Open Channel	Low	moderate	(n/r)	moderate	high	poor	low
Inshore	Very high	very high	high	moderate	very high	high	very high
Shoreline	low	moderate	(n/r)	moderate	very high	poor	low
Tributaries	moderate	high	(n/r)	low	high	poor	low

land	low	moderate	(n/r)	moderate	high	poor	moderate

(n/r indicates no responses from reviewers)

Summing Up

The habitat loss and degradation is insufficiently documented. Data that would shed light on the larger picture and its repercussions are almost non-existent. Instead, there are numerous local studies, split by watersheds, jurisdictions and disciplines. The assessment of the state of the habitats remains almost entirely anecdotal. However, the sheer number of anecdotes and their basic agreement allow only one conclusion, that habitat loss and degradation have been very high, especially in the highly productive and diverse inshore zone and the connecting channels. By and large, the open Lakes are recovering from the eutrophication of the last decades. However, many species associated with them remain threatened because the inshore, shoreline and tributary habitats which they also require have been lost or impaired. The dependence of the lakes and the species that are associated with them on healthy shoreline, inland and tributary habitats has been largely neglected. As a result, the impoverishment of these habitats has hardly registered as a Great Lakes issue.

Most habitat losses to physical changes (e.g. filling, bulkheading, etc.) are likely irreversible. Losses caused by biological and chemical changes have the potential to be reversed. Accordingly, it makes sense to focus on stopping the ongoing pattern of loss and impairment in the present. However, present losses are rarely the large-scale conversion of habitat to other uses. Instead, degradation is more common, in a variety of subtle guises, that truly require an ecosystem approach to understand and reverse.

Accordingly, the next section discusses the various types of impact as a basis for assessing the adequacy of current restoration and protection initiatives.

5.0 Types of Impact on Habitat

The Nature Conservancy (1994) has grouped sixteen types of impact into five major groups. The clarity of this system recommends it for use here. In the following section each of the impacts will be described, and its importance as a threat to each of the habitat types is evaluated as far as information is available.

5.1 Chemical Changes

Because life is based upon the conversion of solar energy to chemical energy and the subsequent use of that chemical energy, changes to the chemical regime of habitats profoundly affects the species that live there.

Table 13: Toxic Chemicals & Nutrients in the Great Lakes

Lake	Public Health Advisories		Contaminant Concentrations	Trophic Status
	Lakewide Restriction	Local Restrictions		
Superior	(none)	In all AOCs*; vary	Lowest	Oligotrophic
Michigan	Trout, Salmon	Several warmwater fish waterfowl	Highest in heavy metals	North-Oligotrophic South-Mesotrophic; eutrophic in degraded areas
Huron	Trout	Catfish, Saginaw Bay; Lake Trout, south of MI Thumb	second lowest	Oligotrophic -Mesotrophic
Ontario	Trout, Salmon	several warmwater fish spp. in certain AOCs*	Highest for organic chemicals, mercury	Moderately eutrophic
Erie	Carp, Catfish	Walleye	Low	Most eutrophic of the lakes
Connecting Channels	(none)	many sport fish St. Clair, Detroit River	Reflect upstream and downstream lakes	reflect upstream lakes

* - *Areas of Concern, as designated by the U.S. and Canadian federal governments on the recommendation of the International Joint Commission*

Toxic Chemicals:
Through the processes of biomagnification and bioaccumulation, the impact of toxic chemicals has been greatest on species at the top of the food chain, such as predatory birds, fish and mammals. The highest concentrations have been observed in top predators in oligotrophic systems, where predators have few prey species, and those prey species in turn feed on a limited number of other species. Because these systems are simple, the potential for biomagnification is

greater.

The example of the bald eagle illustrates the effects of toxic chemicals on birds of prey. Historically the bald eagle nested around the shores of the entire Great Lakes system, and is considered an excellent indicator of clean habitat. Bald eagles were extirpated from many of the islands and shorelines of the Great Lakes in the 1950s and early 1960s, but have recently returned to nest and produce young there (Postupalsky 1985). The primary reason for this localized extirpation was egg shell thinning, caused by p,p'-DDE, the aerobic metabolite of DDT (Colborn 1991). Prior to the widespread use of DDT after World War II, however, 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 (Colborn 1991). Although eagles have returned to the Great Lakes islands and shorelines, they still fail to produce young at a level considered to be associated with a healthy population. Concentrations of p,p'-DDE and PCBs within addled eggs and plasma of nestling eagles are sufficiently great to be of concern (Bowerman et al. 1993; Sprunt et al. 1973).

Fish health and reproduction can also be affected by contaminants. Contaminated sediments in the Detroit River may be toxic to fish eggs spawned there. Contaminants present in fish eggs are believed to be limiting the survival of salmonids during their early life history (egg to swim-up fry). Coho salmon in Lake Erie exhibit thyroid conditions and various syndromes of reproductive dysfunction, including precocious sexual maturation, loss of secondary sexual characteristics, low reproductive hormone levels, reduced egg fertility and high incidence of embryo deformity and mortality (LEP, 1994).

Long-term effects on plants and herbivores are not well understood. Herbicides (e.g. Atrazine) from cropland may be interfering with aquatic plant growth. Herbicides are present in the wetlands and bays of Lake Erie at levels high enough to alter planktonic species composition and inhibit photosynthesis of algal and rooted plant communities. Water soluble metals from sediment pore water can reduce primary production by ultra and pico plankton (LEP, 1994).

While levels of DDT, PCBs and their metabolites will likely continue to decline, the effect of the continuing discharge of other persistent toxic chemicals on the quality of the chemical regime of habitats is not well understood. Toxic bioaccumulating chemicals affect the predators of food webs based in aquatic habitats - open-lake, the inshore zone and tributaries. Thus toxic chemicals are of great concern as they affect the viability of aquatic habitats.

Nutrients

The productivity of the meso- and oligotrophic portions of the Great Lakes are limited by the availability of nutrients; nutrient additions lead to greater productivity. The result of nutrient additions is to force out species that have adapted to low nutrient levels, in favor of those able to better utilize the increased nutrient supply. In aquatic habitats, very high nutrient additions lead to such an increase in productivity that the subsequent decay of the algae and other plants depletes oxygen levels to the point where the other species can no longer survive.

Oxygen depletion as a result of high nutrient levels has been a major impairment of benthic habitats in open-lake, the inshore zone and tributaries. Because nutrient additions have declined, anoxic conditions are no longer widespread. Currently, the main impact of nutrient additions seems to be to reduce the habitat suitable to species that have adapted to low nutrient levels.

However, the reduction in nutrient levels has not always been followed by recovery of the affected communities. Examples include the benthic community in the western basin of Lake Erie, and aquatic plants in the shallow waters of Lake Ontario, neither of which have recovered as expected (LEP, 1994 and Mathers, 1994).

Acidification
Acid deposition from the long-range transport of airborne pollutants has not been seen as a threat to Great Lakes aquatic habitats because the geological buffering capacity seemed sufficient. It has affected inland habitats, especially those on the Precambrian shield which had no buffering capacity. Large scale efforts in the 1980s have reduced the discharge of acid gases to the atmosphere. The long-term effects of present loads on Great Lakes habitats are not known.

Salinity
The storage and use of road salt introduces saline peaks primarily affecting inland tributaries and wetlands. The extent of the stress on species in these habitats is not well understood.

Most of the acute effects of ongoing alterations to the chemical regime seem to be concentrated on bird and fish predators at the top of the aquatic food chain. Some communities have not recovered from major historical degradations. The long-term chronic effects of changes to the chemical regime are not well understood, particularly with respect to the accumulation of persistent toxic chemicals in habitats.

5.2 Hydrologic Changes

The hydrological regime of a habitat affects species composition and long-term community dynamics in numerous ways. Not only are individual species sensitive to water depth and current, and their short-term and seasonal fluctuations, but long-term fluctuations that disrupt community succession are also critical to the maintenance of quality habitat in some cases.

Hydrologic changes which may be most significant to coastal wetlands (besides a total drainage or fill) are the changes occurring from modified flow regimes due to development. Most urban coastal wetlands experience much higher peak flows during storm events and lower base flows at other times. Also, groundwater withdrawal may eliminate groundwater seeps and springs in wetlands, altering the hydrologic regime further and affecting the water quality component of the wetland (Mike Koutnik, Wisconsin Department of Natural Resources, pers. comm.).

Drainage
By far the most significant hydrological change has been the drainage of wetlands, primarily for agriculture. Wetlands in all the habitat types - inland, shoreline and inshore - have been affected. The overall loss is estimated at about 70%, but data on the comparative losses in each of the above categories are not available. Because drainage represents a complete loss of the habitat,

this type of change is treated as a physical alteration in section 5.4.

Water level management
In wetlands, individual plant species and communities of species have affinities and physiological adaptations for certain water-depth ranges. Changes in water level add a dynamic aspect to this species/depth relationship. Water-level dynamics result in shifting mosaics of vegetation types. In general, high water levels kill trees, shrubs, and other emergent vegetation, and low water levels following these highs result in seed germination and growth of a multitude of species. The magnitude of water-level fluctuations is of obvious importance to wetland vegetation. Frequency, timing, and duration are also important characteristics of fluctuations. Water-level changes with a seasonal frequency are likely to have different effects than fluctuations with a frequency of a decade or longer; infrequent, unpredictable fluctuations will result in greater diversity than annual fluctuations. Stable water levels with little fluctuation during the growing season will likely result in stable shoreline plant communities, while unstable summer water levels will likely result in variability in the vegetation.

High water levels (i.e. levels above the historical long-term mean) increase fish access to spawning and nursery habitat in emergent vegetation and increase hemi-marsh habitat (half vegetated, half open water) preferred by waterfowl. Detrital plant materials are also colonized by invertebrates that are fed on by fish and waterfowl. Low water levels can jeopardize fish spawning and reduce waterfowl nesting area; yet, they provide the opportunity for regeneration of the plant communities that are the foundation of the habitat.

The ability of the vegetation to shift with the water levels depends on the slope of the substrate above and below the wetland. Where alterations such as dredging or diking have taken place around the wetlands, the wetland is eliminated during periods of low lake levels. Much more common is the opposite - shoreline development that prevents a shoreward shift of vegetation during periods of high lake levels. When the wetland vegetation can no longer shift rapidly in response to fluctuations, the reestablishment of vegetation takes longer and the wetland is impaired.

The presence of extensive shoreline development, often at the expense of habitat that can buffer lake level fluctuations, has led to intense political pressure to stabilize and control water levels. A study of the impact of major proposed water level regulation scenarios concludes that their implementation would generally greatly reduce wetlands diversity. The lack of a long-term cyclic pattern of peak summertime high lake levels with intermittent low summertime highs means that species richness of the wetlands will likely decline as competitive dominants eliminate more and more species (Wilcox et al. 1993). However fluctuations alone will not provide for wetland vitality without a suitable gradient for vegetation shifts.

Loss of hydrologic connectivity
The viability of communities in many inshore habitats depend on water currents and flows that bring nutrients, sediments and organic matter, and prevent the habitat from drying out. When these currents are altered, as they can be by structures some distance removed from the actual inshore habitat, the habitat is impaired. The construction of groins, breakwaters or alteration of drainage into the inshore habitat are examples of this kind of activity. The extent of the

impairment from such activity is not understood.

The lakeward diking of wetlands, often to improve habitat for waterfowl, cuts off migration routes for spawning, juvenile and predator fishes. Summer and winter kill of fish is frequent in diked marshes because the fish are unable to migrate out to avoid low dissolved oxygen levels or temperature extremes.

Amount and fluctuation of tributary flow
The alteration of the amount and fluctuation of the flow regime in tributaries impairs the habitat for spawning of lake fish and as permanent habitat for other species. The removal of the forest and bankside vegetation tends to increase flooding and low water periods in the summer. Floods flush streams enough to temporarily reduce concentrations of sulphates and chlorides. The scouring action of floods often devastates plant life in or near streams (including overhanging trees and shrubs); epilithic plants and phytoplankton may be dramatically reduced. Seasonal floods can affect fish spawning; for example, eggs of fall-spawning brook trout were decimated by winter floods, and the survival rate of spring-spawned rainbow trout fry increased due to reduced competition from young brook trout. Such changes in species composition may endure for years (Grizell 1976).

The construction of dams may control the worst effects of flooding, but introduces new impairments to tributary habitat, including the physical alteration of habitat, sedimentation, and changes to depth and current velocities. Again, the extent of habitat impairment through hydrologic changes is not understood. The construction of dams has been severely limiting to fish migration throughout the Great Lakes basin.

5.3 Physical Process Changes

Habitats are also defined by physical process and parameters, including temperature and sedimentation.

Temperature changes have occurred primarily in tributaries through the removal of shading bankside vegetation. The narrow temperature requirements of many fish are relatively well documented. Increased temperature fluctuations have restricted the habitat of fish species.

Changes to the thermal regimes of the lakes are also expected. The decrease in nutrient levels has increased water clarity, which in turn increases the depth of the epilimnion (Mayumder and Taylor, in press). Major impacts from warm water outflows from electrical generating plants and other sources have not been documented. The impact of deepwater cooling at the scale proposed for Lake Ontario is currently thought to be small (Boyce et al., 1993).

Sedimentation is a major water pollutant in the Great Lakes Basin. Suspended solids carry pollutants and reduce photosynthesis, oxygen content in water, and the survival rate of invertebrate and fish eggs. They seriously interfere with the food-finding activities of many valuable predator fish, and damage spawning grounds. Tributary and inshore habitats are especially affected.

In other cases, communities have adapted to the regular input of a certain level of sediments and the nutrients they bring. When the sediment-carrying currents are halted or diverted, for instance by groins, breakwaters, dikes and dams, habitats are also degraded.

5.4 Physical Alteration

Large-scale physical alteration and destruction has been the largest source of habitat loss in the inland, shoreline, and inshore zones of the Great Lakes. While the conversion of natural habitats to agricultural, urban and industrial uses has decreased, it has not ended. For wetlands, the most recent estimate is 20,000 acres lost per year in the U.S. to a variety of developments, with an estimated 70% of all wetlands in the Basin already lost, primarily to agricultural drainage. Data for other habitat types are not available, but certain trends are evident:

- Urban lakefilling continues to affect inshore habitats. The rate has decreased, and the current scale is probably relatively limited.
- Dredging and channelling for boat harbours has occurred in many estuaries, especially on the lower lakes, representing a loss of significant inshore habitat (Limno-Tech, 1993).
- Deforestation for agriculture has been the largest source of loss of inland habitats. Temporary losses for timber harvest continue on a relatively large scale, with concerns raised about the loss in quality where old growth forests are being removed. Removal of woodlots and larger second-growth forests continues on the urban fringe of growing cities.
- Development of shoreline for recreation and residential uses continues, seemingly unchecked. The rate of loss of shoreline habitat might be expected to be similar to that of wetlands, as waterfront living continues to be in high demand. In contrast to the infilling of wetlands, the level of concern is low.

The effect of physical alteration on species is straightforward: the habitat is eliminated. An example from the Niagara River illustrates the effect. Two colonies of Black-crowned Night Herons (representing 600 nests) were extirpated from Grand Island, while heron colonies (196 nests) persisted on downstream islands above Niagara Falls. The differentiating observation was that Grand Island has experienced urban development and habitat loss, which did not occur on the downstream islands supporting the latter heron colonies (Limno Tech, 1993).

Non-Consumptive Use Disturbance

A number of species require habitats removed from human disturbance. Wildlife is often sensitive to disturbance at some distance, as the following examples illustrate:

- Mature bald eagles on Michigan's lower Peninsula were found to favor coniferous perches farther from human disturbance than the predominantly deciduous perches of immature eagles (Bowerman and Giesy, 1991).
- Migrating canvasback ducks stopping to rest and feed in the Detroit River do not tolerate boat traffic.

Ambient noise levels and human and pet intrusions into habitats are also known to create stress for wildlife.

Some vegetation communities such as dunes have very low tolerance for the effects of trampling. In dunes, the consequences are especially large because bare spots quickly erode from wind-action.

5.5 Changes to Community Structure

Non-native species

Habitat can be degraded by forces other than physical destruction or contamination, notably the introduction of foreign plant and animal species. Purple loosestrife, the zebra mussel, and others have had a significant negative impact on aquatic and wetlands habitat quality, although the scope and magnitude of these effects are not well understood.

For example, purple loosestrife displaces other plant species, and the species that depend on those plants in wetlands around the basin. Carp have significantly affected inshore habitats in some areas through their resuspension of the substrate fine material in the water column. Higher turbidity prevents the establishment of submergent vegetation and reduces the feeding efficiency of ambush and sight feeders such as pike and bass (LEP, 1994).

Zebra mussels reduce the incubation and hatching success of lake trout and whitefish eggs (Ken Muth pers. comm.). In controlled laboratory studies at the Sandusky Biological Station in Ohio, egg survival and hatching of lake trout was significantly lower in test aquaria containing zebra mussels than in aquaria without mussels. Dissolved oxygen declined and ammonia increased in tanks with zebra mussels, but probably not to lethal levels if water temperatures were cool during incubation. In the lake, fish deposit eggs when water temperatures are warmer, and the metabolism of zebra mussels may increase and alter dissolved oxygen and ammonium concentrations sufficiently to cause egg mortality. There is a possibility that zebra mussels could negatively impact spawning success of these two coldwater fish species even though zebra mussels have evidently caused Lake Erie to become more oligotrophic, which should favor these two species.

In Lake Erie, colonization by zebra mussels and quagga mussels has resulted in the mass extinction of native Unionidae clams (Schloesser and Nalepa in press). Changes in the composition and standing crop of profundal benthos have been linked to the colonization of such substrates by quagga mussels, and the interception of detrital material as it settles.

Further, the Lake Erie stocks of the eastern smelt, the eastern and central basin yellow perch and white perch appear to be declining. These changes are consistent with an ecological role of zebra and quagga mussels intercepting organic detritus that would otherwise have supported secondary production by chironomids, mayflies and amphipods in soft littoral and profundal substrates (LEP, 1994).

To better define the nature and magnitude of the threat posed by the ruffe in the Great Lakes, scientists from the U.S. National Biological Survey-Great Lakes Centre (Tom Edsall pers. comm.)

studied the thermally suitable habitats in the Great Lakes that the ruffe might colonize and identified fish communities that might be most affected bye the ruffe if it spreads into these habitats.

Ruffe grew fastest in laboratory studies at 22 degrees Centigrade, which indicates that it is a coolwater fish as are native Great Lakes percids such as walleye, sauger, and yellow perch. Based on recent estimates of thermally suitable habitat area in the Great Lakes for walleye, 6.5 million hectares should suit the ruffe. Lake Erie, the shallowest and warmest Great Lake had 58% of the total. Lake Huron had 21%, mostly in the North Channel, Georgian Bay, and Saginaw Bay; Lake Michigan and Green Bay had 12%; Lake Ontario, 7%; and Lake Superior, the deepest and coldest lake, 2%.

The potential effects of large populations of ruffe on the fish communities of Lakes Erie, Huron and Michigan are unknown. If ruffe were to become as abundant in all the thermally suitable habitat as in the St. Louis estuary of Lake Superior, it would be a major problem for the Great Lakes fishery. A decline in yellow perch abundance similar to that seen in the St. Louis River estuary would seriously impact the fishery for yellow perch which is presently valued at US $101 million in Lake Erie alone.

Fish Stocking

Community structure needs to be addressed along with habitat considerations. Stocking of fish predators may alter the predator-prey balance in pelagic communities and thus affect water quality. The necessity for addressing the compatibility of water quality (nutrient abatement) objectives and fishery management (predator stocking) strategies is being recognized and is being integrated into ecosystem objectives for various lakes (Bertram and Reynoldson 1992; Superior Work Group 1993).

Other changes to the biological structure of the habitats has resulted from over harvesting of fish and birds which have led to shifts in species dominance and even extinction.

5.6 Impact Analysis

Given the variety and extent of impacts on habitats in the Basin, some effort to evaluate the relative degree of stress posed by each type of impact is needed. Busch et al (1993), set out a system for assessing the degradation of specific habitats based on measurable criteria. This system requires a detailed measuring regime, both of the habitat being studied and nearby non-degraded habitats. This system has not been implemented to date. In the absence of systematic basin-wide monitoring of relative impacts, the Nature Conservancy (1994) has used a simple ranking system based on professional judgement. Results of this evaluation showed greatest stress on biodiversity resulting from habitat destruction, alteration of lake levels and stream flows, and competition from non-native species. Unlike the addition of toxic chemicals and nutrients, whose effects were given a medium score, the physical alterations were seen to be generally irreversible. In establishing priorities to conserve and protect habitat, further analysis and consensus on the relative threat posed by different impacts seems desirable.

6.0 Existing Initiatives

Numerous laws and initiatives in both Canada and the U.S. are designed to protect and restore Great Lakes habitat. The ongoing loss and impairment of habitat suggests they have not yet been successful in reversing the trend of the last two centuries. Whether or not they have slowed the rate of degradation cannot be ascertained as the data are not available or inadequate to accurately determine basin wide trends.

6.1 Research and Information Gathering

Systematic inventories and assessments of habitats on a basin-wide level are not yet being carried out. Bowerman's (1993) study of bald eagle nesting habitat stands out as an isolated exception. Most of the habitat assessment effort to date has focused on wetlands. However, despite ranking among the most studied wetlands in North America, the Basin's wetlands have never been inventoried completely, and only Ducks Unlimited has routinely studied wetlands in both the United States and Canada (Whillans et al, 1992).

Binational Initiatives
The International Tracking System standardizes reporting of wetland restoration, protection, and other data in the U.S. and Canada. Data are available for the fiscal years 1992 and 1993 (October 1, 1991 to September 30, 1993).

Canadian Initiatives
Environment Canada, often in cooperation with other agencies and groups, is gathering habitat related information through a number of programs. An Environmental Sensitivity Atlas for Lake Superior's Canadian Shoreline has been complete for over a year. A draft Environmental Sensitivity Atlas of Lake Huron's Canadian Shoreline has just been completed with the Canadian Coast Guard. A recent Catalogue of Wetland Inventories and Databases confirmed the need for a computerized, comprehensive, current wetland inventory at a uniform scale that could be used to determine wetland area, measure target achievement and monitor change. Historical vegetation community mapping is occurring in a several significant wetlands. Several programs exist to monitor various bird populations, and a program to monitor contaminant levels and health of several indicator species is being expanded.

U.S. Initiatives
The U.S. Environmental Protection Agency has included coastal wetlands as a resource class in its Environmental Monitoring and Assessment Program (EMAP) for the Great Lakes. The EPA has begun to plan pilot and demonstration studies to determine the best way to monitor the condition of wetlands on each of the Great Lakes.

To provide a consistent national database on wetlands, the Nationals Wetlands Inventory (NWI) is classifying and mapping all wetlands in the U.S. from aerial photographs. The information is also being entered into three database systems that will comprise the NWI Geographic

Information System (GIS) and allow computer access to the data. The NWI also prepares wetland trend studies and special reports to Congress.

The digitized NWI database would facilitate ecosystem management, including environmental impact assessment and monitoring, information retrieval, quantitative and qualitative analysis, contaminant studies, fisheries and wildlife studies, restoration, enhancement and protection planning and others. The North American Waterfowl Management Plan (see Section 6.2), in particular would benefit from an NWI digital database (Santos, pers. communication).

The status (February 1994) of NWI mapping is shown in Figure 2. Mapping of some areas of the Great Lakes is complete, but information for the entire U.S. portion of the basin is not expected until after March 1995 (Tom Dahl, personal communication). Digitization of the NWI, lags behind the mapping, with all of Michigan, northern Ohio, and part of New York still to be converted. Wisconsin's wetland database may not be compatible with NWI (Santos, pers. communication).

No comparable program to map other habitat types has been conceived in either country.

Classification Systems

One obstacle to basin-wide inventories is the lack of consensus on an ecosystem wide habitat classification system. In the U.S., the NWI is using the system developed by Cowardin et al (1979) for mapping wetlands. In Ontario, the Ministry of Natural Resources system of evaluating wetlands south of the Precambrian shield based on their hydrological, social, biological and special feature values has seen the most extensive application (Whillans et al, 1992). Data collected under these two systems are not compatible. Busch and Sly (1992) and an international team that included many Canadian and U.S. participants reported on the Aquatic Habitat Classification (AHC) System to facilitate mapping of all types of aquatic habitat. The AHC uses the NWI system and expands it to provide more detailed application to open water and tributary habitats and should be amenable to incorporation in computer database systems (Busch et al, 1993). It is not clear whether data gathered under this system are compatible with the Canadian system, nor has a consensus on the basin-wide use of the AHC developed.

The AHC considers upland areas only in so far as they provide habitat for wildlife populations that rely on the lake for survival (Busch et al, 1993). Compatibility of any basin-wide system to map aquatic habitat, with terrestrial classification systems may also require consideration.

6.2 Habitat Protection

Initiatives

The North American Waterfowl Management Plan (Plan) is a joint Canadian - U.S. - Mexican effort and offers many opportunities for wetland protection and enhancement in the Great Lakes basin. The Plan has among its goals to protect approximately 407,000 acres of critical aquatic and associated upland habitat, enhance approximately 135,000 acres of wetlands, and create approximately 19,000 acres of wetlands. Ongoing losses and alteration of habitat were the reasons for setting these goals. Program implementation has evolved to restoring historical hydrology and vegetation as close as possible. In Ontario, the Plan is implemented through the Eastern Habitat Joint Venture, a partnership of a number of organizations. The Great Lakes ecological zone has been identified as the most significant, and initiatives are under way to secure, preserve and restore wetlands using a broad variety of instruments.

In 1981, Canada became a signatory to the RAMSAR Convention on Wetland of International Importance, Especially as Waterfowl Habitat, and to date thirty wetlands, including three on the Great Lakes, have been identified and protected under legislation.

Canada and the United States have developed a Binational Program to Restore and Protect the Lake Superior Basin. This program focuses on the Lake Superior Ecosystem including the water, air, land and the people of the basin. Of greatest importance to habitat protection are its programs for Special Designations and Habitat in the Basin.

United States

Within the United States, wetlands are managed through a mixture of federal, state and local initiatives, with public input from citizens and interest groups. The federal government's primary tool for protecting wetlands is Section 404 of the Clean Water Act. In accordance with Section 404, the U.S. Army Corps of Engineers (Corps) and the Environmental Protection Agency (EPA) regulate the discharge of dredged or fill materials in "all waters of the United States". Under Section 404 the Corps considers the advice of EPA, the U.S. Fish and Wildlife Service (Service), the National Marine Fisheries Service, other agencies and the public when deciding whether to issue or deny a permit.

One state in the Great Lakes basin (Michigan) has assumed administration of the Section 404 program. Most, but not all, wetland permit actions are handled by the Department of Natural Resources in Michigan. The other states in the basin also have wetland management laws that afford varying levels of protection to wetlands. Each state operates independently according to its own laws.

Federal agencies are obliged to comply with the Federal wetlands Executive Order 11990 and Federal Floodplains Executive Order 11988, which direct that wetland and floodplain impacts should be avoided or minimized to the extent possible. The Order requires specific procedures for agency activities related to: 1) acquiring, managing and disposing of federal lands and facilities; 2) providing federally undertaken, financed or assisted construction and improvements; and, 3) conducting federal activities related to land use.

In 1990 the U.S. Environmental Protection Agency released National Guidance on Water Quality Standards for Wetlands (Environmental Protection Agency 1990a). In this document, EPA regional officials and State Water Quality Managers are required to (1) include wetlands in the definition of "State waters," (2) establish beneficial uses for wetlands, (3) adopt existing narrative and numeric criteria for wetlands, and (4) adopt narrative biological criteria for wetlands, and (5) apply anti-degradation policies to wetlands.

The conservation provisions of the 1985 Food Security Act (Farm Bill) and the 1990 Food, Agriculture, Conservation and Trade Act (FACT Act) have continued to encourage the preservation of a vast acreage of agricultural wetlands and highly erodible croplands. The Swampbuster provision eliminates price supports for individuals who convert wetlands to produce agricultural commodities. In addition, the eight states at least partially within the Great Lakes basin have enrolled a total of over 4.8 million acres in the first twelve Conservation Reserve Program (CRP) signup periods, 13.2% of the national total. Average erosion reduction achieved in the acres signed up in the eight Great Lakes states ranged from 11.0 to 19.9 tons of topsoil per acre over the first ten signups.

Programs and partnerships are underway by the United States Forest Service and several other U.S. Department of Agriculture Agencies. State and local governments are active in habitat initiatives. Within Great Lakes Basin States there are Natural Heritage programs, now also in Canada, although they are focused on natural communities and species more than "habitat." Notable programs in some states include Michigan's Dune Protection Act and Wisconsin's shoreline zoning program, and local watershed councils. Private sector initiatives such as the Nature Conservancy's, Ducks Unlimited and Trout Unlimited are vital to habitat in the Great Lakes Basin. But these are only a partial listing of the important initiatives underway, and more details can be found in The Nature Conservancy (1994) or by contacting the Great Lakes Commission, or by consulting Donahue (1986).

Canada

Environment Canada recently coordinated the development of the Strategic Plan for the Wetlands of the Great Lakes Basin, which aims to protect existing wetlands and achieve an overall increase in the area and function of Great Lakes Wetlands by the year 2020. The priority of the first five year Action Plan is the coastal wetlands of the lower Great Lakes. The Plan was developed with a number of non-governmental organizations and federal and provincial agencies (Patterson, 1994).

Programs aimed at making agriculture more sustainable and compatible with the preservation of wildlife habitat through demonstration, education and research were launched in 1992 and 1993. Another program will provide artificial nesting habitat for bald eagle, osprey and perhaps peregrine falcons (Patterson, 1994).

In Ontario, the most significant mechanism protecting wetlands from impacts resulting from land development is the Planning Act. Under the Act, the Ontario Ministry of Natural Resources can use opportunities in the municipal planning process to ensure development is consistent with its mandate for management of natural resources. In 1992, the Wetlands Policy Statement under Section 3 of the Planning Act was announced. The policy prohibits municipalities from approving development in "provincially significant wetlands" (LEP, 1994).

Nevertheless, the cumulative loss of coastal wetland continues for several reasons:

- The policy statement provides only indirect protection to wetlands that are not provincially significant (Class 4-7).
- Municipal controls under the Planning Act are only as effective as municipal intent to enforce their implementation. This intent may not always be strong - particularly in difficult economic times.

- A legislative equivalent to the Fisheries Act does not exist to provide absolute protection of wetlands. Penalties for wetland destruction are generally small and not a deterrent.
- The Planning Act cannot prohibit landowners from altering the shape of their land prior to the planning process (e.g. a farmer filling in a wetland on his property or a developer clearing and grading a site prior to submitting a draft plan of subdivision of a marina development proposal).

Other Ontario acts and regulations provide the authority to control and restrict discharges and the management of waste. Provincial policies establish that water must be satisfactory for aquatic life.

The Fisheries Act (Canada) provides the best protection for aquatic habitat in Canada, provided that such habitat meets the definition of "fish habitat" for the purposes of this Act. It ultimately prevents any work, without permission, that would cause harmful alteration, disruption, or destruction of fish habitat. This Act also can protect wetlands where fish habitat occurs. Where permission is given to alter habitat, the proponent is required to repair, replace, mitigate and sometimes compensate for these alterations or losses.

6.3 Restoration

Wetlands and aquatic habitat restoration is still a rather young science, with long-term rewards unclear. A fair amount of restoration is being attempted around the Great Lakes system, and while its overall effectiveness in terms of quality is uncertain, it holds a clear potential in terms of offsetting historically lost or altered acreage.

Habitat loss, particularly in the case of wetlands, is in many cases a continuum - a matter of degrees of degradation and/or function loss, rather than an "all-or-nothing" proposition. This means that restoration of function is also not necessarily a simple "yes/no" question: restoration can be partial or incremental as resources or conflicting uses allow. Restoration and protection of partially degraded sites is therefore an important goal; complete re-creation of all natural values is not the only worthwhile goal.

The Great Lakes CleanUp Fund supports habitat enhancement, rehabilitation and recreation in Areas of Concern as well as in other significant wetlands such as the Oshawa Second Marsh, the Dunnville Marshes, the Long Point Wetlands and the Lake St. Clair Wetlands.

A search of the 1992 and 1993 data of the International Tracking System found that 4984.27 acres had been restored and 5874.6 acres protected in U.S. counties which are at least partly in the Great Lakes Basin. The total combined acreage for fiscal years 1992 and 1993 was therefore 10,858.87 acres. Comparing this to the previously quoted estimate of 20,000 acres lost per year basin-wide, both countries appear to be falling well short of just keeping the wetland habitat base they have. Data on the extent and success of Canadian habitat restoration initiatives were not available.

The performance of Basin wetland mitigation and creation programs was addressed by several papers presented at the International Symposium on Wetlands of the Great Lakes (Fishbein 1990; Jahn 1990; Prokes 1990 and others). None of the authors took a basin-wide approach, but rather looked at case study areas ranging from a single permit to multiple-state regions (some states of which are outside the Great Lakes basin). Since that symposium, the U.S. Fish and Wildlife Service has implemented a number of recommendations, including changing restoration efforts to focus more on multi-species, multi-use goals, as opposed to simply aiming for, say waterfowl restoration.

Aquatic habitat restoration efforts have so far not been widespread on the Lakes, nor have many results been well documented or tested, so its potential is unclear.

In a study of mitigation permits in southeast Michigan from 1984 to 1989, Prokes (1990) found the ratio of acres lost to acres created rose from 0.44 to 1.57. While this study does show improvements in mitigation permits, the overall role of mitigation remains limited because more than 99% of all permits issued to degrade wetlands by the Michigan Department of Natural Resources since it started its wetland regulatory program do not require any mitigation whatsoever (Cwikiel, pers. communication).

Prokes (1990) found that although mitigation permits from 1985 to 1987 were generally inconsistently prepared and exhibited high variability, permits from 1988 and 1989 showed significant improvement with more detailed and sophisticated mitigation design and follow-up management requirements included as permit conditions. However, because tracking was not carried out combined with enforcement of mitigation requirements to ensure success, too many projects remain incomplete (although the impacts have already occurred), were poorly constructed, or were not completed in accordance with permit specifications. For example, although a permit may have specified the creation of 3 acres of wetland, because of poor construction design or non-adherence to the permit conditions, less wetland may actually have been created than proposed. In addition, most mitigation projects completed in 1985 and 1986 did not appear to be developing into functionally valuable wetland habitats. Consequently, although no net loss was theoretically achieved as calculated by the loss and creation specified in the mitigation permits, in reality we are probably not only seeing a net loss of wetland habitat acre for acre, but replacement with wetlands that lack the functional values of the original habitat (Prokes, 1990).

Some habitat restoration programs use the habitat requirements of a specific species as their point of departure. Federal and State plans have been formulated for rehabilitating the eastern population of canvasback ducks and their habitat. The Federal plans identify pollution and limited food resources as primary causes of dwindling migration habitat and reduced numbers of birds (USDI 1986), particularly industrial pollution and the loss of wild celery beds in the Detroit River (Oetting 1985). The State plan predicts slow improvement of canvasback habitat in the Detroit River, if pollution controls are continued (Martz et al. 1976). The overall strategy of these plans is to provide adequate migration habitat across the Great Lakes states, rather than crowding fall-migrating canvasbacks into the few pools on the upper Mississippi River where suitable habitat is still available for them.

Jahn (1990) provides a detailed account of the mitigation process as it applied to a single project in Onondaga County, New York. Her conclusions provide poignant testimony to both the state of expectations and reality in mitigating habitat loss within the Great Lakes basin:

> *"Costs are incurred when expectations and reality in a wetland creation project clash. There is a cost to the environment from continued loss of habitat. At this site, nearly three years have passed in which the mitigation wetlands have not been present to compensate for the 1.5 acres of wetland lost to construction. There is a cost to the permittee from the additional work which must be undertaken to satisfy the mitigation requirements of the permit. There is a cost to the resource agency in the form of additional staff review that is required. Ultimately, we as society incur the total cost for wetland creation projects which fail. These costs can be minimized by careful design focused on hydrology, and by an increased awareness of the responsibilities of all parties involved in the permit process, especially the permittee and the resource agencies. We are all responsible to each other for the wise use of our resources."*

6.4 Authorities

Various laws, statutes, policies and agreements are utilized to protect and conserve wetlands and aquatic habitats (Kavetsky 1990; U.S. Department of the Interior and Environment Canada 1986). Besides those highlighted previously in the text, numerous other authorities at the Federal, Provincial, State and local level provide opportunities for protecting and restoring wetlands and habitat in the Great Lakes. These opportunities are obviously not being fully used, since many have been available for decades while the net loss of habitat has continued. A partial list includes authorities for constructing habitat restoration, enhancement and creation projects; planning federally funded, permitted, authorized, or managed public works or other projects; recovery actions and consultations; and rehabilitation and management of wild animals and their habitat.

Authority	Legal Citation, if known	Species or target habitat
International/Binational		
North American Waterfowl Management Plan		Conservation of waterfowl habitat
Migratory Bird Convention		Migratory birds
Great Lakes Water Quality Agreement		Wetland preservation
Strategic Plan for Great Lakes Fisheries Management		Binational management for fish species and their habitats
RAMSAR Convention on Wetlands of International Importance		Important wetlands identified and protected through legislation
United States		
National Wildlife Refuge System Administration Act	16 USC 668dd-668jj	fish and wildlife on all U.S. Fish and Wildlife Service lands
Fish and Wildlife Coordination Act	16 USC 661-667e	fish and wildlife, must be a Federal project
Great Lakes Fisheries Act	16 USC 931-939c	fish habitat, sea lamprey control
Endangered Species Act	16 USC 1531-1543	any listed or candidate species habitat
Migratory Bird Treaty Act and Migratory Bird Conservation Act	16 USC 701-718i	migratory birds
Emergency Wetlands Resources Act	P.L. 99-645	wetlands
Fish and wildlife Act of 1956, as amended	16 USC 742a-742j	fishery and wildlife resources
Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA)	43 CFR 11	construct habitat projects to restore or replace injured resources
Airport and Airway Development Act	49 USC 1701-1742; 84 Stat. 219	habitat

Anadromous Fish Conservation Act	16 USC 757a-757g; 79 Stat. 1125	anadromous fishery resources
Bankhead-Jones Farm Tenant Act	7 USC 1000, 1006, 1010-1012; 50 Stat. 522	"...land conservation and utilization in order to correct maladjustments in land use..."
Estuary Protection Act	16 USC 1221-1226; 82 Stat. 625	pre-acquisition study and inventory of estuaries of the United States, including land and water of the Great Lakes
Federal Power Act	16 USC 791a-825r; 41 Stat. 1063	fish and wildlife resources
Lacey Act of 1900	16 USC 701, 702; 31 Stat. 187, 32 Stat. 285	fish and wildlife, also injurious species controls
Sikes Act	USC 670a-670o; 74 Stat. 1052	fish and wildlife, esp. military and tribal lands
Watershed Protection and Flood Prevention Act	16 USC 1001-1009; 33 USC 701b; 68 Stat. 666	fish and wildlife
Federal Water Project Recreation Act	16 USC 4601-21	facilities for fish and wildlife at all reservoirs under the control of the Secretary of Interior except those within National Wildlife Refuges
Federal Aid in Sport Fish Restoration Act of 1950 (Dingell-Johnson) and (Wallop-Breaux)	16 USC 777-777k	funding to States for management of sport fish (land acquisition, research, development and management projects)
Wildlife Restoration Act (Pittman-Robertson)	16 USC 669-669i	funding to States for land or water adaptable as feeding, resting, or breeding places for wildlife
Coastal Zone Management Act	16 USC 1451-1464	assist State programs to protect, develop and enhance coastal resources
Federal Water Pollution Control Act Amendments	33 USC 1251-1365,1281-1292,1311-1328, 1342-1345, 1361-1376	water quality which provides for protection of fish, shellfish, and wildlife; Bay/Estuary programs

Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990	16 USC 4701-4741	unintentional introductions of nonindigenous aquatic species
North American Wetlands Conservation Act of 1989	16 USC 4401-4412	wetland ecosystems and other habitats for migratory birds and other fish and wildlife
Great Lakes Fish and Wildlife Restoration Act of 1990	16 USC 941a-941g	fish and wildlife resources and their habitats of the Great Lakes basin
Canada		
Migratory Bird Convention Act		Protects migratory birds and habitat
Canada Wildlife Act		
Federal Policy of Wetland Conservation		
Federal Fisheries Act		Protects fish habitat
Ontario Planning Act		Allows Min. of Natural Resources input into municipal planning
Ontario Public Lands Act		requires permit for work on Crown Land
Ontario Lakes and Rivers Improvement Act		requires work permit if project will affect water movement in streams either on public or private lands
Ontario Environmental Assessment Act		requires environmental assessment for government works and selected private proposals
Ontario Wetlands policy statement		Under Planning Act; municipalities must have regard for policy in all land use decisions

Some solutions to the various environmental stresses that cause losses and alteration of wetlands have to be implemented at the lowest level of government. Advice, advocacy, data, education, funding and lobbying offered by any group to local clientele may facilitate a solution. Successful local management ordinances are often those with: 1) an underpinning of sound technical data, a comprehensive plan, and evenhanded administration; and 2) a partnership between the

Federal/State/Province, the local community, and its citizens in developing and implementing the ordinance.

7.0 Management Implications

Conservation actions aimed at protecting diversity, productivity and function of the Great Lakes Basin must strategically address the key sources of stress. First efforts need to focus on protecting habitats that are most important to the basin's ecosystem. They must also concentrate on reducing key sources of stress, and do so sustainably in a variety of socioeconomic settings that represent the diversity of challenges present in the basin. Integral to all actions is the need to gain a better understanding of what key species and communities need to survive.

Four major types of strategic activity are recommended to protect the habitats of the basin:

1) Developing strategically-coordinated, locally-based and driven projects that collectively address the most significant systems and stresses;

2) Improving the basic and applied science necessary for habitat conservation;

3) Increasing awareness of the basin's ecosystem and of methods to protect it;

4) Increasing the support of regional institutions, both governmental and private, for the protection of habitats.

Among the reasons for ongoing wetland losses are varying levels of commitment to wetlands protection, inconsistent administration of programs, and slow development of protection policy. Despite heightened public awareness, there are still many who view a wetland as a future agricultural field, shopping mall, or housing development. There are hopeful signs, however (Functional Group 2 1989). Actions needed include:

1. Protection of remaining wetlands should be encouraged by restricting shoreline development and managing for production of fish and wildlife, where this is compatible with the wetland's historic and current functional values. "Attractive nuisances" for fish and wildlife contamination should be avoided.

2. The restoration of wetlands where they once existed or new wetlands on sites where there is a high likelihood of success should be encouraged in and along the Lakes, Interconnecting channels and tributaries.

3. Boaters should be discouraged from entering areas where large numbers of migratory waterfowl feed and rest in the spring and fall.

4. No new construction of closed dike systems that totally isolate wetlands from the lake and reduce wetland functions.

A wide variety of management decisions have widespread, often unintended effects on wetlands and coastal habitat: nutrient levels and inputs, species introductions, water level controls, etc. as previously mentioned. What is believed to be needed to better protect and restore wetlands and other natural habitat is probably not more laws, but rather better implementation and enforcement of existing authorities. For example, the Great Lakes Water Quality Agreement commits the federal governments to efforts to protect habitat and wetlands. A previous section of this chapter lists more than 20 authorities that can serve as tools to better protect, enhance, restore and create habitat throughout the Great Lakes basin, provided the resources are committed to this important effort.

Use of the Great Lakes, their interconnecting channels, and tributaries for the dilution and disposal of liquid and solid wastes is in clear conflict with the basic biological processes in these waters, including the production of valuable fish and wildlife resources. However, many conflicts between uses should be resolved by implementing the following recommendations.

1. Sewage treatment plants discharging into the Lakes, interconnecting channels, and their tributaries should be upgraded to tertiary effluent level for organic matter and heavy metals, and operated at design standards.

2. Combined sewer overflows and industrial discharges to the Lakes, interconnecting channels, and their tributaries should be reduced and their toxic substances content should be more adequately monitored.

3. New connections to sewers that have insufficient storm water capacity should be delayed until combined sewer overflows are eliminated.

4. Contaminated sediments should be removed from catch basins and sewer pipes that discharge into the Lakes, interconnecting channels and their tributaries.

5. Heavily polluted sediments should be dredged (with no overflow), decontaminated, and disposed of in acceptably designed, managed and monitored confined disposal sites, preferably on land.

6. Confined disposal facilities should be protected and managed for the benefit of fish and wildlife, but only if studies show such sites are not toxic to plants and animals.

7. Adequate containment safeguards around hazardous substance storage and handling facilities on shore should be installed and maintained to prevent oil and contaminant spills into the Lakes, Interconnecting channels and tributaries, especially during winter.

8. A public education and involvement campaign should be launched to promote the Lakes, interconnecting channels, and their tributaries as valuable natural resources, discourage pollution of them, and generate support for planned pollution control efforts. The Lake Superior Binational Program and many other efforts provide good examples of such campaigns.

The present state of knowledge about habitats, their extent and quality, and the stresses that affect them is not adequate to set priorities for protection and restoration, nor in many cases, to decide which action to take to best protect and restore habitat. There are many research needs, too numerous to list here, that must be addressed.

Many initiatives to protect and restore the Great Lakes ecosystem are planned and under way. Integrating habitat considerations into these initiatives will increase their effectiveness. Habitat programs should be involved in developing:

- Contaminated sediments remediation;
- Great Lakes confined disposal facilities;
- Remedial Action Plans;
- Lakewide Management Plans;
- Water Quality Standards;
- Watershed Plans;
- Risk assessment Modelling;
- Spill responses;
- Non-indigenous species strategies;
- Landscape planning;
- Educational tools on ecosystem health;
- Lake Superior Binational program;
- Fish community objectives; and
- Fish population restoration projects.

Conclusion

Clearly the health of habitat and wetlands is a major concern in the Great Lakes Basin. A number of programs, laws and policies already exist to enhance habitats in the Great Lakes Basin. What is needed to better protect and restore wetlands and other aquatic habitats is probably not more laws, but rather stronger will to conserve habitats, implementation and enforcement of existing laws, regulations and policies. Coupled with this need for improved implementation and policy is the need for a strategic approach to habitat protection and restoration, making full use of all levels of partnerships.

8.0 References

Anonymous. 1992. Status of the Lake Ontario Offshore Pelagic Fish Community and Related Ecosystems in 1992. (Kingston, Ontario: Lake Ontario Committee of the Great Lakes Fisheries Commission).

Anonymous. 1994. Contribution to the SOLEC Habitats and Wetlands Working Paper: Lake Erie. (unpublished)

Atkinson, J. 1994. Contribution to the SOLEC Habitats and Wetlands Working Paper: Connecting Channels. (unpublished).

Balesic, H. 1979. "Literature Review of the Physical Characteristics and Fishes of the Northern Nearshore Zone of Lake Ontario," Ontario Hydro Research Division Report. No. 79-165-K. Toronto: Ontario Hydro.

Bedford, B. L. 1990. Increasing the scale of analysis: The challenge of Cumulative Impact Assessment for Great Lakes Wetlands. Proceedings: International Symposium on Wetlands of the Great Lakes, Niagara Falls, NY pp. 186-195.

Bellrose, F. C., and R. D. Crompton. 1970. Migrational behavior of mallards and black ducks as determined from banding. Ill. Nat. Hist. Surv. Bull. 30(3):167-334.

Bertram, P. E. and T. B. Reynoldson. 1992. Developing ecosystem objectives for the Great Lakes: policy, progress and public participation. Journal of Aquatic Ecosystem Health. 1:89-95.

Botts, L. and B. Krushelnicki. (1987). The Great Lakes: an Environmental Atlas and Resource Book. United States Environmental Protection Agency and Environment Canada. 44 pp.

Bowerman, W. W., IV. 1993. Identification of potential bald eagle nesting habitat along the Great Lakes. Chapter 4 in Regulation of bald eagle (Haliaeetus leucocephalus) productivity in the Great Lakes Basin: An ecological and toxicological approach. PhD Dissertation, Michigan State University pp. 75-115.

Bowerman, W. W., and J. P. Geisy, Jr. 1991. Ecology of bald eagles on the Au Sable, Manistee, and Muskegon Rivers. Final report to Consumers Power Company (WP NO. 412E322) Hydroelectric Project Environmental Studies: Bald eagle Studies. Michigan State University Department of Fisheries and Wildlife, Pesticide Research Centre, Institute for Environmental Toxicology, East Lansing.

Bowerman, W. W., D. A. Best, J. P. Geisy, T. J. Kubiak, and J.K. Sikarskie. 1993. The influence of environmental contaminants on bald eagle populations in the Laurentian Great Lakes, North America. IV World Conf. on Birds of Prey, Berlin.

Boyce, F.M., P.F. Hamilton, L.D. Harvey, W.M. Schertzer and R.C. McCrimmon. 1993. Response of the Thermal Structure of Lake Ontario, 1750-2050. (Occasional Paper 90-8) Buffalo, N.Y.: State University of New York).

Bridger, K.C. and D.A. Oster. 1981. Lake Ontario Tactical Fisheries Plan. Ontario Ministry of Natural Resources.

Busch, W.-D., M. Lazeration, M. Smith, and M. Scharf. 1993. 1992 Inventory of Lake Ontario Aquatic Habitat Information. U.S. Fish and Wildlife Service, Lower Great Lakes Fishery Resources Office, Amherst, New York.

Busiahn, Tom. 1994. Personal communication.

Busiahn, T.R. (ed.). 1990. Fish Community Objectives for Lake Superior. Great Lakes Fishery Commission Special Publication 90-1.

Christie, W.J. 1972. "Lake Ontario: Effects of Exploitation, Introductions, and Eutrophication on the Salmonid Community," Jour. Fish. Res. Board Canada. Vol. 29 No.6: 913-929.

Colborn, T. 1991. Epidemiology of Great Lakes bald eagles. J. Toxicol. Environ. Health 33:395-453.

Cowardin, L.M., V. Carter, F.C. Golet, E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-79/31.

Cwikiel, Wil. 1994. Personal communication.

Dahl, T.E., 1990. Wetlands Losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 21 pp.

Donahue, M. J. 1986. Institutional arrangements for Great Lakes management: past practices and future alternatives. Doctoral dissertation, University of Michigan, Ann Arbor, Michigan. 551 pp.

Edsall, T.A., E.F. Stoermer and J.P. Kociolek. 1991. "Periphyton accumulation at Remote Reefs and Shoals in Lake Superior," Journal of Great Lakes Research. 17(3):412-418.

Edwards, C. J., Hudson, P. L., Duffy, W. G., Nepszy, S. J., McNabb, C. D. , Haas, R. C., Liston, C. R., Manny, B. A., and Busch, W. N. 1989. Hydrological, morphometrical, and biological characteristics of the connecting rivers of the International Great Lakes: A review. In Proceedings of the International Large river symposium, D. P. Dodge, Editor. Can. spec. Publ. Fish. Aquat. Sci. 106:240-264.

Fishbein, N. 1990. Restoring Agricultural Wetlands: An Analysis of the U.S. Fish and Wildlife Service Wetland Restoration Program. Proceedings: International Symposium on Wetlands of the Great Lakes, Niagara Falls, NY pp. 222-225.

Functional Group 2. 1989. Living with the Lakes: Challenges and Opportunities Annex B Environmental features, Processes and Impacts: an Ecosystem perspective on the Great Lakes - St. Lawrence River System. International Joint Commission Water Levels Reference Study. 169 pp. + Appendices

Great Lakes Basin Commission. 1981. Great Lakes Basin Plan: Wetlands Policy Plan with Final Environmental Impact Statement. Ann Arbor, Michigan, 43 pp. In Functional Group 2, (1989).

Grizell, R.A. 1976. Flood Effects on Stream Ecosystems. Journal of Soil and Water Conservation. 31(6):283-285

Headrick, M.R. 1976. Effects of Stream Channelization on Fish Populations in the Buena Vista Marsh, Portage County, Wisconsin.
Office of Biological Services, Fish and Wildlife Service, 38 pp.

Herdendorf, C. E. and S. M. Hartley, and M. D. Barnes, eds. 1981. Fish and wildlife resources of the Great Lakes coastal wetlands within the United States. Volume one: Overview. U. S. Fish and Wildlife Service. Washington, D. C. FWS/OBS-81/02-v1. 469 pp.

Herdendorf, C. E., C. N. Raphael and W. G. Duffy. 1986. The Ecology of Lake St. Clair Wetlands: A Community Profile. Fish and Wildlife Service. U. S. Dept. of the Interior, Washington, D. C.

Hurley, D.A. and W.J. Christie. 1977. "Depreciation of the Warmwater fish community in the Bay of Quinte, Lake Ontario," Jour. Fish. Res. Board Canada. Vol. 34: 1849-1860.

International Joint Commission. 1981. Great Lakes Water Quality Board 1981 Report to the IJC on Great Lakes Water Quality. 74 pp.

International Lake Erie Regulation Study Board. 1981. Lake Erie Water Level Study. Report to the International Joint Commission, Windsor, Ontario, 166 pp.

Iwachewski, E. 1994. Contribution to the SOLEC Habitats and Wetlands Working Paper: Lake Superior Habitat Aquatic Habitat. Ontario Ministry of Natural Resources (unpublished).

Jahn, K. 1990. A Wetland Creation Project in Onondaga County, New York: A Comparison of Expectations with Reality. Proceedings: International Symposium on Wetlands of the Great Lakes, Niagara Falls, NY pp. 226-230.

Kahl, R. 1991. Boating Disturbance of Canvasbacks during migration at Lake Poygan, Wisconsin. Wildl. Soc. Bull. 19:242-248

Kavetsky, R. T. 1990. Integrating International Agreements with Cooperative Projects to Better Protect Great Lakes Wetlands. Proceedings: International Symposium on Wetlands of the Great Lakes, Niagara Falls, NY pp. 292-295.

Kerr, S.J. and G.C. LaTendre. 1991. The State of the Lake Ontario Fish Community. (Special Publication 91-3) Great Lakes Fish Commission.

Koonce, J.F. 1994. The State of Aquatic Community Health of the Great Lakes. Great Lakes Fishery Commission, Ann Arbor, Michigan, prepared for the State of the Lakes Ecosystem Conference.

Krishka, B.A. 1989. St. Mary's River Remedial Action Plan Background Fish Community, Habitat and User Information. OMNR Report.

Lawrie, A.H. 1978. "The Fish Community of Lake Superior," cited in "Limnology of Lake Superior," Journal of Great Lakes Research. M. Munawar (ed.) Vol.3 No.s 3-4: 247-254.

Limno Tech. 1993. Great Lakes Environmental Assessment. (Michigan: National Council of the Paper Industry for Air and Stream Improvement).

Liskauskas, A. unpublished. Contribution to the SOLEC Habitats and Wetlands Working Paper: Lake Huron Habitat and Wetlands. (unpublished).

LSBP (Lake Superior Binational Program). 1993. Volume II: Draft Stage 1 Lakewide Management Plan.

Martz, G. F., J. Aldrich, and D. Ostyn. 1976. History and future of Canvasback populations in Michigan's Great Lakes habitat during fall migration and early winter. Mich. Dept. Nat. Resour., Wildl. Div. Rep. No. 2759. Lansing. 22 pp.

Mathers, A. 1994. Contribution to the SOLEC Habitats and Wetlands Working Paper: Lake Ontario Habitat Description. (unpublished).

Mazumder, A. and W.D. Taylor. (in press). "Thermal Structure of Lakes in Varying Size and Water Clarity." Limno. Oceanogr.

Mills, H. B., W. C. Starrett, and F. C. Bellrose. 1966. Man's effect on the fish and wildlife of the Illinois River. Ill. Nat. Hist. Surv., Biol. Note 57. 24 pp.

Murkin, 1979. on p 24 of original paper by B. Kavetsky et al.

Nielson, M., S. L'Italien, V. Glumac and P. Bertram. 1993. State of the Lakes Ecosystem Conference Paper: Nutrients: Trends and System Response.

Oetting, R. B. 1985. Restoration of canvasback migration habitat in the lake states. Presented at Waterfowl in Winter Symposium, January 7-10, 1985. Galveston, Texas. U. S. Fish and Wildlife Service. Unpubl. Rep. Twin Cities, Minn. 12 pp.

Patterson, N. 1994. SOLEC Habitats and Wetlands Working Paper: Environmental Conservation Branch Contribution. Environment Canada, Environmental Conservation Branch (unpublished).

Postupalsky, S. 1985. The bald eagles return. Natural History 87:62-63.

Prokes, J. A. 1990. Status and Trends of Wetland Mitigation Practices in Southeastern Michigan: An Agenda for the 1990's. Proceedings: International Symposium on Wetlands of the Great Lakes, Niagara Falls, NY pp. 231-240.

Richards, J.S. 1976. Changes in Fish Species Composition in the Au Sable River, Michigan from the 1920's to 1972. Transactions of American Fisheries Society 105(1):32-40.

Ryder, R.A. 1965. "A Method for Estimating the Potential Fish Production of North-Temperate," Lakes. Transcontinental American Fisheries Society. Vol 94, No. 3: 214-218.

Santos, Kim. 1994. Personal Communication.

Schloesser, D. W. and B. A. Manny. 1990. Decline of Wildcelery buds in the lower Detroit River, 1950-1985. J. Wildl. Manage. 54(1):72-76.

Schloesser, D. W. and T. F. Nalepa. in press. Dramatic decline of Unionid bivalves (Bivalvia: Unionidae) in offshore waters of Western Lake Erie after infestation by the zebra mussel. in press Can. J. Aquat. Sci.

Sprunt, A., IV, W. B. Robertson, S. Postupalsky, R. J. Hensel, C. C. Knoder, and F. J. Ligas. 1973. Comparative productivity of six bald eagle populations. Trans. No. Am. Wildl. Nat. Res. Conf. 38:96-106.

Superior Work Group. 1993. Ecosystem Principals and Objectives for Lake Superior Discussion Paper. Lake Superior Binational Program, State of the Lake Superior Basin Reporting Series Volume IV. 16 pp.

The Nature Conservancy. 1994. The conservation of biological diversity in the Great Lakes Ecosystem: Issues and Opportunities.. Great Lakes Program, Chicago, Illinois 118pp.

Trauger, D. L., and J. R. Serie. 1974. Looking out for the canvasback. Part III. Ducks Unlimited 38(5):44-45,60,64,71-72.

U.S. Army, Corps of Engineers. 1987. Corps of Engineers Wetlands Delineation Manual.

U.S. Army, Corps of Engineers. 1989. Final environmental impact statement supplement II; operations, maintenance and minor improvements of the Federal facilities of Sault Ste. Marie, Michigan (July 1977) Operation of the lock facilities to 31 January + 2 weeks. Detroit.

U.S. Department of the Interior and Environment Canada. 1986. North American Waterfowl Management Plan. A strategy for Cooperation.

U.S. Fish and Wildlife Service. 1988. Final Fish and Wildlife Coordination Act Report on Biological Resources Impacted by the proposed Navigation Season Extension to January 31 + 2 weeks on the Upper Great Lakes. East Lansing Michigan Enhancement Field Office. 183 pp + appendices.

U.S. Fish and Wildlife Service. 1993. Listed Species and Designated Critical Habitat that may be affected by the Great Lakes Water Quality Guidance.

Weller, M. W. and C. E. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Agr. Home Econ. Exp. Sta. Iowa State University Special Report No. 43 Ames. 31 pp.

Weller, M. W. and L. H. Fredrickson. 1973. Avian Ecology of a Managed Glacial Marsh. Iowa Agr. and Home Econ. Expt. Sta. No. 7403, 22 pp.

Wetzel, R. G. 1992. Wetlands as Metabolic Gates. J. Great Lakes Res. 18(4):529-532.

Whillans, T.H. 1980. Feasibility of Rehabilitating the Shore Zone Fishery of Lake Ontario. Background paper for the Lake Ontario Fisheries Tactical Plan prepared under the contract to the Lake Ontario Tactical Planning Committee. OMNR.

Whillans, T.H. 1982. Changes in marsh area along the Canadian shore of Lake Ontario. J. Great Lakes Res. 8(3): 570-577.

Whillans, T.H., R.C. Smardon, and W.-D. Busch. 1992. Status of Lake Ontario Wetlands. Great Lakes Research Consortium Working Paper, SUNY College, Syracuse, New York.

White, R.J. 1975. Trout population responses to streamflow fluctuation and habitat management in Big Roche-a-Cri Creek, Wisconsin. Verhandlungen, Internationale Vereinigung fur Theoretische und Angewandte Limnologie. 19:2469-2477.

Wilcox, D. A., J. E. Meeker, and J. Elias. 1992. Impacts of Water-level regulation on wetlands of the Great Lakes. Phase II Report to Working Committee 2. IJC Water Level Reference Study

8.1 Other Sources Used

Erickson, R.E. and M.E. Hubbell. 1992. Atlas of the National Wetlands Inventory Maps in the Chicago Metro Area. U.S. Fish and Wildlife Service, National Wetlands Inventory (Twin Cities), MN. 20 pp. and Appendices.

Smith, G.S. 1991. NWI MAPS MADE EASY: A User's Guide to National Wetlands Inventory Maps of the Northeast Region. U.S. Fish and Wildlife Service, National Wetlands Inventory, Newton Corner, MA. 15 pp.

U.S. Fish and Wildlife Service. 1985. USER's GUIDE National Wetlands Inventory Information and Legend for Map Products. Portland, OR. 12 pp.

U.S. Fish and Wildlife Service. 1990. Photo Interpretation Conventions for the National Wetlands Inventory. St. Petersburg, FL. 45 pp. and Appendices.

U.S. Fish and Wildlife Service. 1991-1992. Unpublished National Wetlands Inventory Fact Sheets and Information.

U.S. Fish and Wildlife Service. 1993a. NWI MAPS MADE EASY A User's Guide to National Wetlands Inventory Maps of the Mountain-Prairie Region. Denver, CO. 16 pp.

Under "Recommendations and Suggested Actions" above, we quoted:

U. S. Department of the Interior. The Impact of Federal Programs on Wetlands, Vol. II, A Report to Congress by the Secretary of the Interior, Washington DC, 1994.

8.2 Acknowledgements

The following individuals contributed input, information, assistance or ideas helpful to the compilation of this cluster paper:

Ron Erickson and Kim Santos, U.S. Fish and Wildlife Service, National Wetlands Inventory, Bloomington, Minnesota.
Tom Dahl, National Biological Survey, National Wetlands Inventory, St. Petersburg, Florida.
Darryl York, National Biological Survey, Information Transfer Center, Ft. Collins, Colorado.
John Gannon, Bruce Manny, Doug Wilcox, and Tom Edsall, National Biological Survey-Great Lakes Center, Ann Arbor Michigan.
Bob Beltran, Environmental Protection Agency, Great Lakes National Program Office, Chicago Illinois.
David Rankin, The Nature Conservancy, Great Lakes Program, Chicago, Illinois.
Paul Botts, Chicago, Illinois.
Bob Payne, Agricultural Stabilization and Conservation Service, East Lansing, Michigan.
Tom Kerr, U.S. Fish and Wildlife Service, Refuges and Wildlife, Twin Cities, Minnesota.
Tom Busiahn, U.S. Fish and Wildlife Service, Fishery Resources Office, Ashland, Wisconsin.
Carolynn Bohan, U.S. Fish and Wildlife Service Great Lakes Coordination Office, East Lansing, Michigan.
Alastair Mathers, Rob MacGregor, Arunus Liskaukas, Ed Iwachewski, Jim Atkinson and their associates in the Great Lakes Branch, Ontario Ministry of Natural Resources.
Nancy Patterson and associates in the Canadian Wildlife Service of Environment Canada.
Members of the SOLEC Steering Committee and Technical Subcommittee.

We apologize to anyone inadvertently overlooked, or whose comments on earlier drafts could not be addressed due to time constraints.

9.0 Post-conference Addendum

This was prepared in response to the five "Participant's Question and Comment Forms" and two comment letters provided by the Conference Organizers.

General

On the basis of comments received concerning several of judgement-based habitat assessments, further information suggests these may be taken out of context and misused. The author of this comment didn't provide subjective corrections to any of these judgments as they appeared in the tables, however. The working paper authors feel that they serve a purpose in providing something to start with and do not believe the potential for misuse is significant. They have been clearly identified as professional judgment from the outset, and this judgment is being relied upon only until the sorely-needed information called for in the Working Paper becomes available.

Definition of Habitat

One comment concerning the definition of habitat suggested that food and cover resources should be discussed with it. The early drafts of this paper had no "definition of habitat" because it means so many different things to so many different Great Lakes species. The authors added a definition which was particularly broad and uncomplicated because of the audience and scope of the paper.

Recommendations and Suggestions for Action

Comments also included a caution that the recommendations and suggestions for action provided in the final section may be premature based on the acknowledged lack of sufficient information to assess impacts. Further information suggests that these recommendations and suggestions for action were not out of line. The first priority articulated in the "Loss of Biodiversity" sessions at SOLEC was "a comprehensive information base and species inventory <u>but action to protect biodiversity should be undertaken simultaneously</u>" (The SOLEC Indicator, 10/27/94).

Additionally, another comment noted the need for a cost-benefit analysis. A Participant Question and Comment Form contained the following:

> "Financial policies are mentioned in several parts of the SOLEC paper, and a recent Federal report points out how U. S. Federal financial support has had negative impacts.
>
>> 'Restricting federal financial support for unsound development cannot be relied on as the only conservation tool. It will help to conserve the remaining resource base, but it cannot mitigate for lost wetlands or restore degraded ones. It should, however, be among the first approaches to the problem of continuing wetland loss and degradation. Many [U.S.] federal programs that affect wetlands adversely are designed and financed in ways that violate the beneficiary pay principal of public finance. These programs distort market signals and provide subsidies that have

> had negative environmental effects. Optimally, these programs should be redesigned in order to confront those who benefit from the programs and projects with the full cost of their activities. If an activity cannot pay for the full cost of the resources which it uses, it is inefficient to allocate the resources to it by subsidization and inequitable to ask taxpayers to finance the costs.'

The same report, released after finalization of the SOLEC paper, made one major recommendation for the Great Lake state it described:

> 'Have federal agencies assess the effects of their programs on wetlands. Where feasible, agencies should minimize the wetlands effects of their programs.'

These impacts are also occurring in the Canadian portion of the Basin, similar solutions may apply." (Reference in "Peer-Reviewed References" section below).

Rate of Net Loss

On the basis of comments received concerning Section 5.4, which quoted a 20,000 acre per year loss estimate made by the Great lakes Basin Commission (1981) and Functional Group 2 (1989), further information suggests it may not reflect the current situation. This estimate was included in the Working Paper because it was the only guess made, on a Great Lakes Basin-wide scale, of the magnitude of the ongoing net loss before or since that time. The working paper authors would have gladly quoted another conjecture but none was found for the basin-wide scale. It points up a lack of "common currency" between jurisdictions, states, provinces and nations that was obvious from the Working Paper and presentation of it at SOLEC. The comment form making this point, from the Michigan Department of Natural Resources, went on to state that many state and federal regulatory programs, land acquisition, tax incentive and financial assistance programs are in place to protect and restore aquatic habitat resources. Very strong authorities and laws exist in the State of Michigan to protect coastal wetlands, lakes and streams as well as inland wetlands. The authors could conclude from this argument that the rate of net loss has been substantially reduced, however the data upon which the original estimate was made is over 20 years old and no one has stepped forward to publish a better one since. Identifying this data gap justifies SOLEC.

Influencing Decision-Making

The remainder of the Working Paper Breakout Session Participant's Question and Comment Forms related to the issue of how we as scientists and managers can influence decision making. One comment stated that the two important items that influence politicians or decision makers to make worthwhile decisions are votes and dollars. The comment urges lobbying and identifying what influences votes. The comment also urges quantifying in economic terms the benefits of protecting or restoring habitat. Another comment form asked: "With such a huge portion of the original wetland habitat acreage altered or converted to different land usage types, shouldn't there be a moratorium on any future alteration or conversion? Shouldn't all remaining wetland habitat be regarded and classified as critical?" Understanding wetland values and functions withing the larger Great Lakes St. Lawrence River Ecosystem, such as the information eventually publicized for the Everglades, the comment went on to say, would strengthen arguments for Great Lakes wetland preservation. Another comment stated that recreational and economic values need to be considered functions that should be considered as indicators of significance. The authors agree. That same comment suggested adding more to the Lake-by-Lake descriptions to fully describe the wetlands of significance and impacts that have occurred. This would have increased the size of the document considerably, which was beyond the recommended size almost from the start. It is nonetheless a worthy goal, and could make a useful outgrowth document. The information is available from diverse sources. Other details were noticed in this comment letter, including lack of solutions for introduced species like carp and purple loosestrife, and major research initiatives at the University of Guelph directed at controlling purple loosestrife. More Canadian habitat restoration data is becoming available and should be included in the next SOLEC. In general this letter found that impoundment projects in Canada have been very successful while experimental techniques remain questionable. Mitigation failures were felt by the author of this letter more closely linked to execution of the effort. Finally, this letter called for selective use of impoundments rather than what was perceived in Action 4 at the bottom of page 57 to be a total ban on diking. The authors agree that there need not be a rigid ban against all diking, rather the important point is not to "totally isolate wetlands from the lake and reduce wetland functions." Need for this level of detail was not anticipated.

Another comment stated that the paper needed a stronger pitch for a universal "ranking/classification" system as crucial for decision-making. It was not the authors' intent to recommend one system over another, and a critical evaluation of the myriad systems in use was certainly beyond the scope of what was originally supposed to be limited to a 30-page paper. The same comment recommended an International Joint Commission committee/Forum on this issue. The authors would support this idea. The comment also called for targetted communication, education and involvement plans, particularly for community-based grass roots involvement and buy-in. Finally, this comment asked for economic and human health integration of issues. The message should be that we need a healthy ecosystem in order to be healthy physically and economically. If we promote that more, and quantify it, then the policy changes, etc. will come. The authors and the SOLEC Integration paper support this message, but again showing it is beyond the scope of the Habitat Paper.

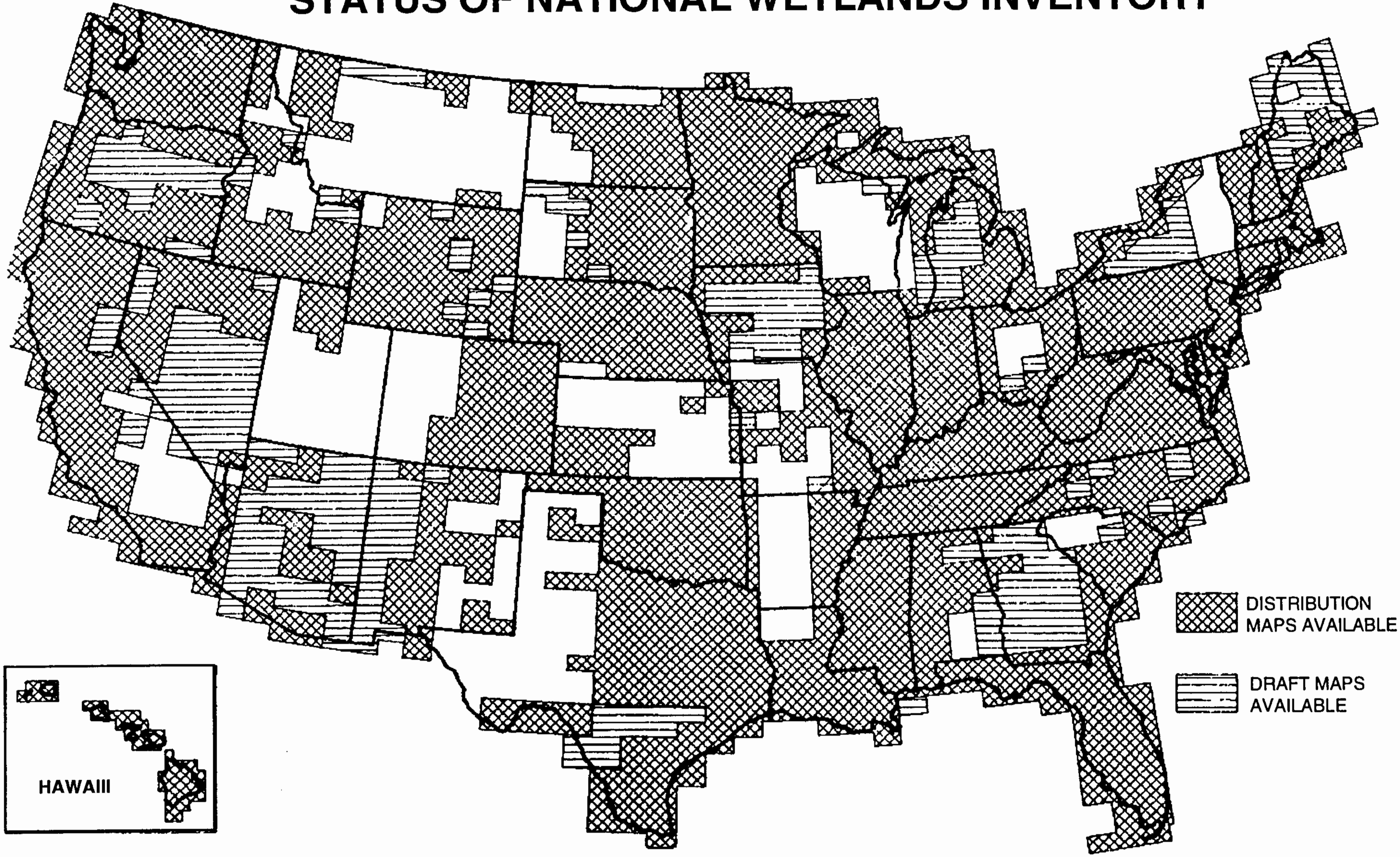
Partners

On the basis of comments received concerning protection of shorebird habitats and partner agencies in the Eastern Habitat Joint Venture, the authors acknowledge leaving out some details. We apologize to the Partners in the Eastern Habitat Joint Venture, who are:
Canadian Wildlife Service
Ministry of Natural Resources
Ministry of Agriculture, Food and Rural Affairs
Agriculture Canada
Nature Conservancy of Canada
Wildlife Habitat Canada

Peer-Reviewed References

One comment asked for a greater number of peer-reviewed reference citations, which "would be a useful addition to the paper." The authors felt great frustration at the lack of current basinwide habitat data. This necessitated piecing together what information was out there in grey literature reports in order to give any kind of a Great Lakes basinwide summary. The lack of information was acknowledged in the paper, but we were certainly not in the position of being able to generate research reports on our own, on a basinwide scale, to distill down to what was originally supposed to be a 30-page summary paper. We hope identification of this gap will stimulate other Great Lakes basinwide habitat data to be published in a peer-reviewed form. It is sorely needed.

STATUS OF NATIONAL WETLANDS INVENTORY



THIS GRAPHIC SHOWS GENERALIZED INFORMATION. FOR DETAILED INFORMATION ON SPECIFIC AREAS, TELEPHONE 1-800-USA-MAPS (IN VIRGINIA 1-703-648-6045).

FEBRUARY 1994