GREAT LAKES FISHERY COMMISSION

2004 Project Completion Report[1]

DRAFT Environmental Objectives for Lake Huron: Draft Report of the Environmental Objectives Working Group of the Lake Huron Technical Committee

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Environmental Objectives for Lake Huron

Draft Report of the Environmental Objectives Working Group

of the

Lake Huron Technical Committee
Great Lakes Fishery Commission

January 21, 2004

Working Group Members:

Arunas Liskauskas	Ontario Ministry of Natural Resources (Chairperson)
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INTRODUCTION

To better facilitate the cooperative management of fisheries resources in the Great Lakes, the Great Lakes Fishery Commission (GLFC) proposed *A Joint Strategic Plan for Management of Great Lakes Fisheries* (Joint Plan) in 1980 (GLFC 1994). This commitment to inter-jurisdictional coordination of fisheries management was based upon an ecosystem approach which followed a common goal for all the Great Lakes:

> *"To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery reared fish, and provided from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, employment and income, and a healthy human environment."*

Included in the Joint Plan was a directive for all Lake Committees to develop Fish Community Objectives (FCOs) for each lake. The FCOs would describe a "desirable" fish community based upon accepted ecological concepts and guiding principles. To further facilitate and support these efforts, development of Environmental Objectives (EOs) describing the biological, chemical and physical needs of desired fish communities, was also considered a critical step in the successful implementation of the Joint Plan. The revised Joint Plan (GLFC 1997) further reaffirmed and expanded on the need for developing EOs.

The consideration of an ecosystem approach that recognizes the critical link between fish community structure and its living environment was further emphasized in the *Strategic Vision of the Great Lakes Fishery Commission for the First Decade of the New Millennium* (GLFC 2001). The following vision statement regarding healthy aquatic ecosystems was formulated:

> *"The commission shall encourage the rehabilitation and conservation of healthy aquatic ecosystems in the Great Lakes that provide sustainable benefits to society, contain predominantly self-regulating fish communities, and support fisheries with increasing contributions of naturally reproducing fish. Conserving biological diversity through rehabilitation of native fish populations, species, communities, and their habitats has a high priority."*

The FCOs for Lake Huron were completed in 1995 (DesJardine et al. 1995). In 2002, the Lake Huron Committee (LHC) received Coordination Activities Program funding from the GLFC for the production of EOs for Lake Huron. The Lake Huron Technical Committee (LHTC) confirmed participation and membership in a Lake Huron EO Working Group in January of 2003.

This document provides draft EOs for Lake Huron including Georgian Bay and the North Channel that summarize the major environmental impediments to achieving FCOs. In many cases desirable endpoints for environmental conditions are not quantified due to a lack of information or incomplete knowledge of environment/fish community relationships. However, the identification of environmental factors affecting fish community structure and function will provide awareness and direction for future inquiries into environmental impacts.

The draft EOs represent the impressions of a limited number of resource agency representatives. Further review by additional resource agency representatives and stakeholders will be required before they are finalized.

The focus of this exercise includes the entire Lake Huron watershed, starting at the compensation gates on the St. Marys River and downstream of the Mackinaw Bridge, and continuing to the outflow of Lake Huron at the St. Clair River, including all watersheds draining into the main basin, Georgian Bay and the North Channel. In addition, Lake Huron shoreline areas affected by lake hydrology or affecting nutrient loading and sedimentation have also been included (Figure 1).

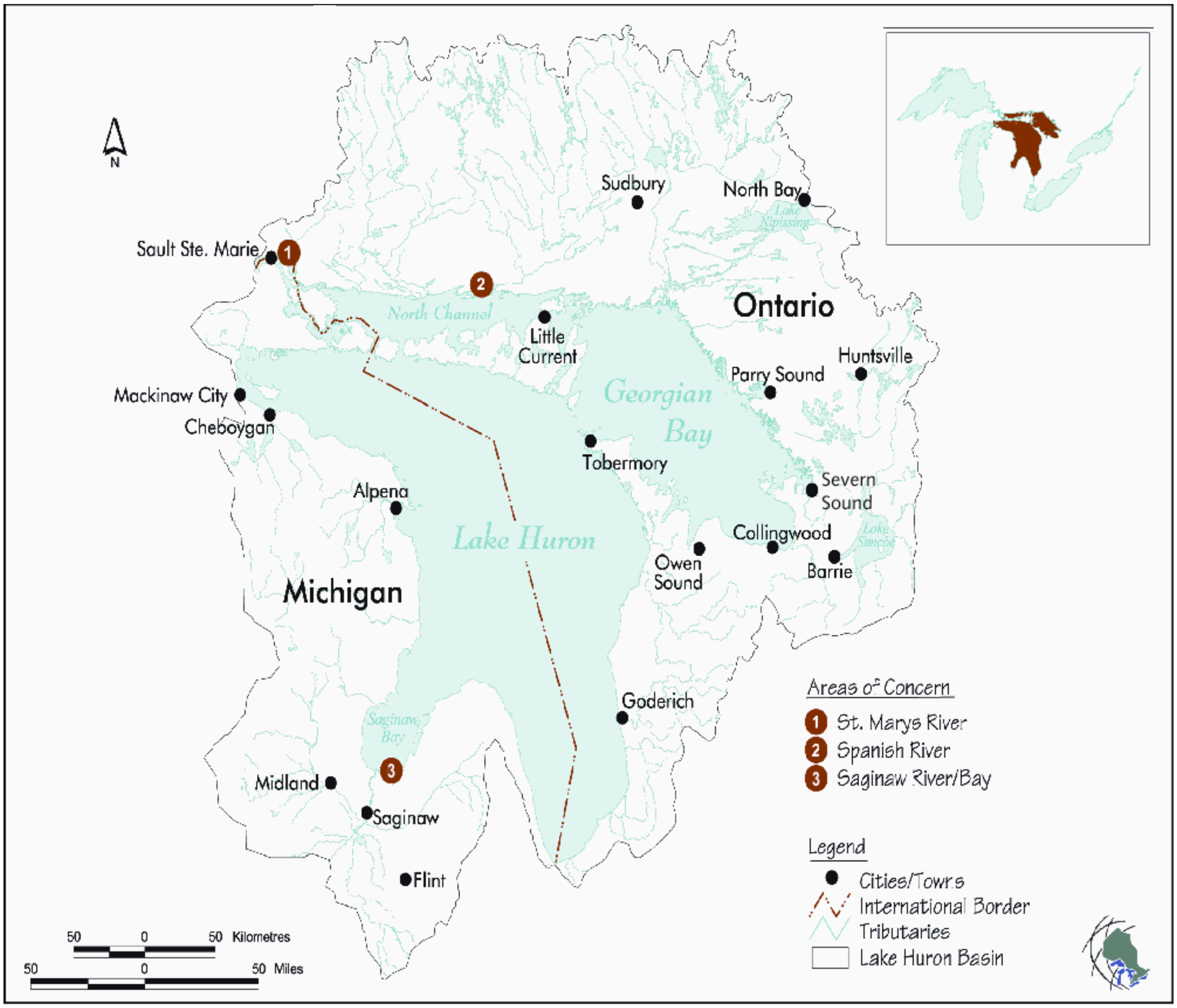

Figure 1. The Lake Huron basin and watershed including population centers and Areas of Concern. Prepared by: Environment Canada - Atmospheric Environment Branch, Geomatics Unit.

ACCOUNTABILITY AND ROLES

The task of developing EOs for Lake Huron was delegated by the Lake Huron Committee (LHC) to the EO Working Group of the LHTC. The EO Working Group, comprised of provincial, state, tribal and federal agency representatives, was responsible for coordinating the EO development process. The chair of this working group had the primary responsibility to coordinate the EO development process and compile, organize and synthesize the EO documentation.

The Lake Huron Working Group included:

Arunas Liskauskas (chair)	Ontario Ministry of Natural Resources
Jim Johnson	Michigan Department of Natural Resources
Mark McKay	Michigan Department of Natural Resources
Aaron Woldt	US Fish and Wildlife Service
Tom Gorenflo	Chippewa/Ottawa Resource Authority
Jim Bredin	Michigan Department of Environmental Quality

The Lake Huron EOs Working Group drew upon the expertise of agency representatives that are directly involved with fisheries management, however, since the environmental objectives involve an ecosystem approach, the participation of other agencies, organizations and individual ecosystem specialists have played a critical supporting and advisory role. The following individuals have provided support in a variety of ways to the Lake Huron EO development process:

Jamie Shardt	US Environmental Protection Agency
Janette Anderson	Environment Canada
Rich Rudolph	Fisheries and Oceans Canada
David J. Ross	Fisheries and Oceans Canada
Pat Chow-Fraser	McMaster University
Marg Dochoda	Great Lakes Fishery Commission

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INTEGRATION AND IMPLEMENTATION

The development of the Lake Huron EOs has benefited from a number of completed or ongoing initiatives that focused on various aspects of aquatic resource management and research. These initiatives provided supporting documentation and were compatible with efforts aimed at understanding ecosystem function and change as it relates to fish community structure. Related initiatives include:

- **The State of Lake Huron In 1999** (Ebener 2003), which describes the status of fish stocks and their habitats including recommendations for achieving FCOs.
- **The State of Lake Huron 1999 Symposium,** sponsored by the GLFC (www.glfc.org/pubs/SpecialPubs/2000Huron/contents.asp).
- The Michigan Department of Environmental Quality **Lake Huron Initiative Action Plan** (Bredin 2000)**,** aimed at concerns and actions necessary for the restoration and protection of the Lake Huron basin and watershed (www.deq.state.mi.us/lhi/).
- The **Lake Huron GIS** project providing data integration and basin wide inventory of aquatic resource information (www.glfc.org/GLGIS/).
- The **Lake Huron Bi-National Partnership** facilitation of information sharing and priority setting for bi-national environmental protection and restoration activities in the Lake Huron Basin.
- The Lake **Huron Federal/Provincial Working Group** providing Canadian agency support for integrated lake-wide management and planning and bi-national initiatives.
- The **State of the Lake Ecosystem Conference (SOLEC) ’96, ’98, ’00, ’02,** development and assessment of indicators and identification of management challenges and actions (www.epa.gov/glnpo/solec/).
- The **International Lake Huron Basin Symposia** (Munuwar et al. 1995) provides a holistic and integrated overview of the Lake Huron ecosystem.

Developed Lake Huron EOs will provide guidance to fisheries management agencies and non-government organizations (NGO) on Lake Huron for initiating actions that are necessary for the achievement of FCOs. For the EOs to be practical and relevant they need to address issues of concern at various spatial scales and timeframes. The level of detail provided in this document is aimed at providing multiple options and therefore flexibility in addressing issues of concern. However, the detailed description of policy, regulations and specific actions needed to achieve each objective are beyond the scope of this document. The Lake Huron EOs should be viewed as a living document and as such will require periodic reviews and revisions to maintain its relevancy.

GUIDING PRINCIPLES

The draft EOs for Lake Huron are intended to provide practical and effective suggestions to overcome existing environmental impediments that are acting as barriers to achieving FCOs. In order for these EOs to be relevant and accessible they should be consistent, to the extent possible, with the following properties:

- Address current and emerging ecosystem issues (nutrient inputs, climate change, stocking and prey base dynamics, changes in food web structure, etc.)
- Identify critical habitats and their attributes (ex. wetland size, integrity, diversity)
- Where possible be quantifiable (provide desirable end-points)
- Address habitat impairment issues identified in the FCOs
- Promote and maintain biodiversity (genes, populations, communities and landscapes)

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LAKE HURON FISH COMMUNITY OBJECTIVES: AN OVERVIEW

The Lake Huron Environmental Objectives were developed to compliment and support the Lake Huron Fish Community Objectives. A summary of the Lake Huron FCOs is presented to provide important background and context. The ecological concepts and guiding principles found in the FCOs provide an important framework and supporting rationale for the management directions being proposed in the draft EOs.

Overall Objective
Over the next two decades, restore an ecologically balanced fish community dominated by top predators and consisting largely of self-sustaining, indigenous and naturalized species capable of sustaining annual harvests of 8.9 million kg.

Salmonine (Salmon and Trout) Objective
Establish a diverse salmonine community that can sustain an annual harvest of 2.4 million kg, with lake trout the dominant species and anadromous (stream-spawning) species also having a prominent place.

Percid (Walleye and Perch) Objectives
Reestablish and/or maintain walleye as the dominant cool-water predator over its traditional range with populations capable of sustaining a harvest of 0.7 million kg.
Maintain yellow perch as the dominant nearshore omnivore while sustaining a harvestable annual surplus of 0.5 million kg.

Esocid (Northern Pike and Muskellunge) Objectives
Maintain northern pike as a prominent predator throughout its natural range.
Maintain muskellunge in numbers and at sizes that will safeguard and enhance its special status and appeal.
Sustain a harvestable annual surplus of 0.1 million kg of these esocids.

Channel Catfish Objective
Maintain channel catfish as a prominent predator throughout its natural range while sustaining a harvestable annual surplus of 0.2 million kg.

Coregonine (Lake Whitefish and Ciscoes) Objectives
Maintain the present diversity of coregonines.
Manage lake whitefish and ciscoes at levels capable of sustaining annual harvests of 3.8 million kg.
Restore lake herring to a significant level and protect, where possible, rare deepwater ciscoes.

Centrarchid (Bass and Sunfish) Objective
Sustain smallmouth and largemouth bass and the remaining assemblage of sunfishes (Centrarchidae *spp.*) at recreationally attractive levels over their natural range.

Sturgeon Objectives
Increase the abundance of lake sturgeon to the extent that the species is removed from its threatened status in United States waters.
Maintain or rehabilitate populations in Canadian waters.

Prey Objective
Maintain a diversity of prey species at population levels matched to primary production and predator demands.

Sea Lamprey Objectives
Reduce sea lamprey abundance to allow the achievement of other fish community objectives.
Obtain a 75% reduction in parasitic sea lampreys by the year 2000 and a 90% reduction by the year 2010.

Species Diversity Objective
Recognize and protect the array of other indigenous fish species because they contribute to the richness of the fish community. These fish – cyprinids, rare ciscoes, suckers, burbot, gar, and sculpins- are important because of their ecological significance; intrinsic value; and social, cultural, and economic benefits.

Genetic Diversity Objectives
Maintain and promote genetic diversity by conserving locally adapted strains.
Ensure the strains of fish being stocked are matched to the environments they are to inhabit.

Habitat Objectives
Protect and enhance fish habitat and rehabilitate degraded habitats.
Achieve no net loss of the productive capacity of habitat supporting Lake Huron fish communities and restore damaged habitats.
Support the reduction or elimination of contaminants.

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PROCEDURE FOR DEVELOPMENT OF ENVIRONMENTAL OBJECTIVES

The Lake Huron EO Working Group used the following strategy for completing the charge of developing EOs:

1) A series of working group sessions was scheduled to critically review the existing FCOs and develop draft EOs for Lake Huron using agency member input. The procedures followed for developing EOs were modeled after those developed by the Lake Erie Environmental Objectives Sub-Committee (Halyk et al. 1999) of the Lake Erie Committee (GLFC). An Environmental Objectives workshop was held in October of 2002, and served as a forum for habitat experts across the Great Lakes to present an update on the status of habitat research and information needs across the Great Lakes. Working Group sessions were scheduled in April and October of 2003 and facilitated efforts at evaluating draft EOs by reviewing their relevance to FCOs, identifying primary species and life stages impacted by environmental issues, describing the main issues, summarizing current and historic data, and identifying priorities and information needs.

2) A review of draft Lake Huron EOs with environmental, habitat and ecosystem experts is proposed to take place in the fall of 2004. This session would confirm that all relevant environmental and habitat issues have been addressed in the draft EOs. The identification of critical habitats, Biodiversity Investment Areas (BIA) and environmental issues that may impede the achievement of FCOs would be critically reviewed at this meeting.

3) Upon completion of these sessions, a final draft EOs document would be completed incorporating all recommendations and be submitted to the LHC for review in January 2005.

4) The solicitation of public and non LHC agency input would be initiated through circulation of the draft Lake Huron EOs during the spring and summer of 2005.

The final version of the Lake Huron EOs would be completed after review of comments from the public, LHC and the GLFC.

DRAFT ENVIRONMENTAL OBJECTIVES FOR LAKE HURON

This section presents the four draft environmental objectives for Lake Huron and provides background, description of issues, historic and current information, priority management areas, and information needs. The summarized draft Environmental Objectives are:

1) **Spawning and Nursery Habitats**

   Maintain, protect and restore the integrity and connectivity of wetland spawning, nursery and feeding areas throughout the Lake Huron basin.

   Protect and restore connectivity and functionality of tributary spawning and nursery areas throughout the Lake Huron Basin.

   Protect and restore reef spawning areas throughout the Lake Huron Basin.

2) **Shoreline Processes**

   Protect and rehabilitate nearshore habitats and reestablish the beneficial structuring forces of natural water exchanges, circulation, and flow that they provide.

3) **Food Web Structure and Exotics**

   Protect and where possible enhance or restore fish community structure and function by promoting native species abundance and diversity and avoiding further exotic species introductions. In particular, protect and restore keystone predators to control exotic species and cultivate a food web favorable to reproduction of native species.

4) **Water Quality**

   Protect and restore water quality throughout the Lake Huron basin, especially in the Areas of Concern, and reduce or remove contaminant burdens from the fish community in order to avoid reductions in fish production and native species biodiversity, and to maintain fishable, swimable, aesthetically unaltered waters for the enjoyment of future generations.

1.1 Spawning and Nursery Habitats (wetlands)

Maintain, protect and restore the integrity and connectivity of wetland spawning, nursery and feeding areas throughout the Lake Huron basin

Relevance to Fish Community Objectives:

Fish Community Objectives	Importance of Environmental Objective
Re-establish and/or maintain walleye as the dominant cool-water predator over its traditional range with populations capable of sustaining a harvest of 0.7 million kg. *Maintain yellow perch as the dominant nearshore omnivore while sustaining a harvestable annual surplus of 0.5 million kg.*	*Walleye and yellow perch are found throughout the shallow littoral zones of Lake Huron and in many cases closely associated with wetland areas. A number of walleye and yellow perch populations use vegetated areas of wetlands for spawning purposes. Wetland areas found in river estuaries and adjacent coastal areas provide protective cover and feeding areas for juveniles of both these species.*
Maintain northern pike as a prominent predator throughout its natural range *Maintain muskellunge in numbers and at sizes that will safeguard and enhance its special status and appeal* *Sustain a harvestable annual surplus of 0.1 million kg of these esocids.*	*Northern pike and muskellunge are obligate wetland species requiring access to coastal, estuarine, and riverine wetlands for spawning and nursery habitat. Adults of both species use vegetated coastal and floodplain wetland areas for egg deposition. Fry and juveniles of both species depend on wetlands to provide necessary cover and feeding areas.*
Sustain smallmouth and largemouth bass and the remaining assemblage of sunfishes at recreationally attractive levels over their natural range.	*Basses (Centrarchids) in general rely on wetland areas for part of their life cycle. Largemouth bass are the most dependent on wetlands for providing vegetated areas for spawning and nursery habitat. Smallmouth bass, pumpkinseed, rock bass and black crappie also utilize these areas for nursery and feeding purposes.*
Maintain Channel catfish as a prominent predator throughout its natural range while sustaining a harvestable annual surplus of 0.2 million kg.	*Channel catfish are found in shallow, warmwater areas of Lake Huron and are particularly abundant in large wetland areas of Saginaw Bay and south-eastern Georgian Bay. These coastal wetlands are important feeding areas for channel catfish.*

Maintain a diversity of prey species at population levels matched to primary production and to predator demands.	*The major prey species of Lake Huron can be found at one time or another in association with coastal wetlands. These wetlands provide prey fish with varying amounts of spawning, nursery and feeding areas and offer protective cover from predators.*
Recognize and protect the array of other indigenous fish species because they contribute to the richness of the fish community. These fish- cyprinids, rare ciscoes, suckers , burbot, gar, and sculpins- are important because of their ecological significance; intrinsic value; and social, cultural, and economic benefits.	*Coastal wetland habitats throughout Lake Huron are characterized by having high fish species diversity and in some cases acting as refuge areas for rare or threatened species.*
Protect and enhance fish habitat and rehabilitate degraded habitats. *Achieve no net loss of the productive capacity of habitat supporting Lake Huron fish communities and restore damaged habitats.* *Support the reduction or elimination of contaminants.*	*Historical losses of coastal wetlands have occurred throughout much of the Lake Huron basin. Incremental losses and degradation of remaining coastal wetlands continues. Shoreline armoring and alteration has fragmented many wetlands and in many cases has completely disconnected these wetlands from the lake proper. Wetlands also filter nutrients and sediments from runoff waters and are especially important in filtering runoff from agricultural areas such as Saginaw Bay. Protecting remaining wetlands, reconnecting segregated wetlands and rehabilitating degraded ones will contribute to the preservation of fish community diversity and overall aquatic ecosystem productivity.*

Background:

Although Lake Huron is recognized as a deep, oligotrophic lake, it also has an expansive shoreline covering over 7,000 km with the inclusion of the St. Marys River, Manitoulin Island and the 30, 000 islands of Georgian Bay (International Joint Commission 1989, 1993). This complex shoreline with its myriad of sheltered embayments, islands and rivermouths has given rise to the formation of extensive wetlands particularly in Saginaw Bay, the St. Marys River, and eastern Georgian Bay. This complexity, along with the lakes varied geology, makes these wetlands some of the most diverse across the Great Lakes (Smith et al. 1991). These coastal wetlands are utilized as spawning, nursery and feeding areas by a variety of facultative and obligate wetland dependent fish species.

Coastal wetlands throughout the Great Lakes have been recognized as critical areas for fish production. These wetlands contribute large numbers of sport, prey and commercial species to Great Lakes fisheries (Herdendorf et al. 1986; Herdendorf 1987). Estimates vary on the number of species utilizing coastal wetlands in the Great Lakes. Whillans (1987) estimated that over 90% of the roughly 200 fish species in the Great Lakes were dependant on wetlands for at least some part of their life-cycle whereas Jude and Pappas (1992) found 47 species closely associated with coastal wetlands. Numerous important sport fish species were strongly connected to coastal wetlands including northern pike, muskellunge, largemouth bass, smallmouth bass, bluegill, yellow perch, white crappie, black crappie, channel catfish, black bullhead, brown bullhead, carp and bowfin (Raphael and Jaworski 1979; Jude and Pappas 1992).

The structural diversity of wetlands represented by submergent, floating and emergent vegetation is important to numerous fish species. The eggs of yellow perch are often found adhering to vegetation (Scott and Crossman 1973) and yellow perch spawning in Saginaw Bay and Les Cheneaux Islands appears to be associated with marshes (MDNR, unpublished data). Both northern pike and muskellunge spawn in heavily vegetated flooded areas (Scott and Crossman 1973). Young northern pike are occasionally stranded in marshes or wet meadows when water levels are dropped, cutting off their escape to the open water. Appropriate management of water level control devises, particularly on waterfowl marshes and inland lakes, is effective in reducing stranding losses (Eddy and Underhill 1974). Thus, accessible marsh habitats are critical to the reproduction of these species.

Maintaining, protecting and restoring the integrity and connectivity of Lake Huron basin (including the St.Marys River) wetlands will ensure that critical spawning, nursery and feeding habitats are available for esocids, centrarchids, percids, ictalurids, and a variety of prey fish. Maintaining the integrity and widespread availability of these coastal wetlands will assist in preserving rare and regionally significant species that add to biological diversity in the Lake Huron basin. Functioning wetlands also act as biological filters, trapping sediment and taking up nutrients from runoff water. As such they serve to protect reefs and other sensitive substrates from sedimentation and nutrient enrichment.

Description of issues:

The distribution, size, accessibility and integrity of coastal wetlands throughout the Lake Huron basin have been affected to varying degrees. A summary of issues affecting Great Lakes and connecting channel wetlands was provided by Maynard and Wilcox (1997). Natural stressors on coastal wetlands included water level change, sediment supply and transport, ice and storm damage as well as natural biological stressors. Human-induced stressors included drainage, filling and dredging, shoreline modification, water-level regulation, changes in sediment budgets, nutrient enrichment, toxic chemicals, non-native species, climate change, diking wetlands and road crossings. The degree to which these stressors are affecting Lake Huron basin coastal wetlands is not well known.

Losses of Lake Huron basin wetland areas have occurred, however, no comprehensive estimate of coastal wetland loss is available (Maynard and Wilcox 1997). Along the Michigan shoreline of Lake Huron it is estimated that 20% of coastal wetlands have been lost through dredging, draining and infilling (Bredin 2000). Although similar estimates are unavailable for most of the Ontario shoreline, some coastal wetlands such as those found in the Severn Sound area of southern Georgian Bay, have been reduced in size by 18-68% (Severn Sound Remedial Action Plan 1993). Incremental loss of coastal wetlands continues to be a concern in both the St. Marys River

(Williams and Lyon, 1991; Bray 1992) and Lake Huron basin (Severn Sound Remedial Action Plan 1993; Maynard and Wilcox 1997).

The impact of other human stressors on the Lake Huron basin wetlands is not well understood. Some wetland areas in Saginaw Bay and along the St. Marys River have been impacted by excessive sedimentation or contaminants (Kauss 1991; Nichols et al 1991; Bray 1992; Bredin 2000). Ongoing stresses from coastal shipping continue to affect St. Marys River wetlands through increased current speed, wave action, erosion and turbidity (Duffy et al. 1987; Kauss 1991). The effects of nutrient enrichment, sedimentation and contaminants on wetlands in the Severn Sound area of southern Georgian Bay and the Spanish River delta of the North Channel have largely been remediated and both areas are considered to be recovered from these stressors (Spanish River Remedial Action Plan 1999; Severn Sound Remedial Action Plan 2002).

A number of future stresses may have significant negative repercussions on Lake Huron basin coastal wetlands. The incremental loss of wetland area continues in locations experiencing increased development pressure. Reduced species richness, loss of cyprinids and increases in tolerant species resulted from increased development in the Les Cheneaux Islands area (Gathman and Keas 1999). The proliferation and spread of exotic species such as purple loosestrife, phragmites, zebra mussel and round gobies may compromise the integrity and function of existing coastal wetlands. Exotic species such as the common carp have had a negative impact on coastal wetlands by reducing the diversity and biomass of macrophytes (King and Hunt 1967; Crivelli 1983; Lougheed et al. 1998). Climate change and its potential to permanently lower water levels may reduce the size, complexity and accessibility of some wetlands. The lack of linkage between local land use planning and broader strategic objectives aimed at no net loss of fish habitat may result in the continued decline of wetlands and fish production. The value of coastal wetlands particularly as it relates to fish production and diversity needs to be reinforced at all levels of resource management decision making.

The future status of wetland areas and their ability to provide the necessary requirements for maintaining the distribution and abundance of a variety of fish species throughout the Lake Huron Basin is uncertain. A majority of coastal wetland areas in the Lake Huron basin have yet to be formally evaluated. For most of the evaluated wetlands trends in spatial coverage and integrity are not being monitored. The extent to which unevaluated coastal wetlands are utilized by a variety of species, particularly those that are rare, threatened or endangered remains an unknown throughout a large portion of the basin.

Summary of current and historic data:

Information on the distribution and characteristics of coastal wetland areas in the Lake Huron basin continues to be compiled. A recent examination of the health of coastal wetlands in the Great Lakes (Maynard and Wilcox 1997) concluded that no comprehensive inventory or evaluation of Great Lakes wetlands exists. Subsequent efforts have been made to develop an inventory across the Great Lakes (Chow-Fraser and Albert 1998) and the Lake Huron basin specifically (Ball et al. 2003). Detailed wetland evaluations have been conducted for a number of wetlands along the Michigan shoreline of the St. Marys River (Liston et al. 1986; McNabb et al. 1986), however, these evaluations are dated and in need of an update. A majority of coastal wetland areas in Ontario waters of Lake Huron, particularly in northern Georgian Bay, the North Channel, and the St. Marys River have yet to be formally evaluated.

Coastal wetlands are found throughout the Lake Huron basin with concentrations in Saginaw Bay, St. Marys River, eastern Georgian Bay and the Detour/Drummond Island/Les Cheneaux Islands areas. Lake Huron basin wetlands are characterized by having very complex vegetation communities and are primarily marsh and swamp types with some bog and fen components (Liston et al. 1986; Smith et al. 1991; Ball et al. 2003). The aerial coverage of coastal wetlands in Michigan waters is estimated to be 24,400 ha (Bredin 2000) with over 5,300 ha of wetlands along the St. Marys River. Although most wetlands in Ontario waters have not been evaluated, wetland area in Georgian Bay is estimated to be 12,600 ha (Bookhout et al. 1989) with an additional 7,100 ha evaluated along the Ontario shoreline of the St. Marys River (Ball et al. 2003).

The association between wetland areas and fish community composition is not well established on Lake Huron. The few surveys that have been conducted in the basin revealed that 59 fish species utilized coastal wetlands either permanently or on a temporary basis (Prince et al. 1992; Severn Sound Remedial Action Plan 1993) with largemouth bass, rock bass, bluntnose minnows, pumpkinseed and banded killifish the most common permanent residents (Severn Sound Remedial Action Plan 1993). The significance of wetland areas for muskellunge was established in recent reviews of their distribution in the basin (Liskauskas 1996) and identification of spawning areas (Craig and Black 1986; Fielder et al. 2003). In addition, 11 rare or provincially significant fish species were observed to use Lake Huron wetlands (Sutherland 1994; Mandrak and Crossman 1992).

More detailed information on fish community composition associated with Lake Huron coastal wetlands can be found from surveys conducted in Areas of Concern (AOC) identified by the International Joint Commission (IJC) as well as recent efforts initiated by the Nature Conservancy in the Les Cheneaux Islands area (Gathman and Keas 1999). Results from work conducted on the St. Marys River, Spanish Harbour and Severn Sound, have found high species diversity in wetland areas and confirmed their significance in providing spawning, nursery and feeding habitats (Duffy *et al.* 1987; Bray 1993; Spanish River Remedial Action Plan 1999; Severn Sound Remedial Action Plan 1993; Randall et al. 1998). Similar results showing high species diversity and the importance of marshes as nursery habitat for yellow perch were found in the Les Cheneaux Islands coastal wetlands (Gathman and Keas 1999) and in Saginaw Bay (Fielder et al. 2000).

Priority areas and issues:

The value of wetlands as primary fish production areas and centers of biodiversity have been well established. Maintaining the productivity of coastal wetlands in Lake Huron can be accomplished through the protection of existing wetlands. Regaining lost fish production can be accomplished through the restoration of degraded wetlands, the creation of new wetlands, and reconnecting those isolated from Lake Huron by removal of barriers. The goal of no net loss of coastal wetlands should be looked upon as a high priority.

The following is a list of Priority Management Areas (PMAs) and some of their attributes:

Saginaw Bay

- Largest concentration of coastal wetlands in the Lake Huron Basin
- Upper watershed development causing sedimentation and chemical contamination of sediments in coastal wetlands
- Historically supported largest production of percids (yellow perch, walleye) in the Lake Huron basin
- Continues to be an important area for centrarchid production (smallmouth bass, largemouth bass, black crappie, sunfish, rock bass) and ictalurids (channel catfish)
- Historically supported large esocid populations that are currently reduced
- Still experiencing shoreline development pressure and wetland loss
- Impacted by exotic species (zebra mussels, round gobies, common carp)
- Many coastal wetland areas no longer connected to open lake waters
- Further protection and monitoring of coastal wetlands is required

St. Marys River

- Extensive wetland areas with many requiring evaluation
- Impacts from shipping, ice breaking, industrial and recreational development continue
- Supports diverse warm and coolwater community with many wetland dependent fish species
- Supports important walleye stock and a muskellunge population that may need rehabilitation
- Northern pike widely distributed and utilizing existing local wetlands for spawning
- Wetland evaluation and monitoring a priority

Les Cheneaux Islands

- Area of extensive coastal wetlands
- Some historic loss of coastal wetlands
- Area supports a diverse fish community
- Critical habitat for yellow perch
- Possible nutrient enrichment problems
- Shoreline development pressure continues
- Wetland evaluation and monitoring a priority

Eastern Georgian Bay/North shore of North Channel

- Large coastal area with wetlands interspersed throughout with many yet to be inventoried
- Supports diverse warm and coolwater fish community
- Severn Sound and Magnetewan River have high density of coastal wetlands that are under intense recreational development pressure
- Muskellunge and northern pike utilize these coastal wetlands for spawning
- Area supports high diversity of centrarchids (largemouth bass, smallmouth bass, rock bass, sunfish, black crappie)
- Impacts from exotic species (zebra mussels, round gobies) becoming more prominent
- Spanish River delta wetlands recovering from historic environmental impacts and site of muskellunge recovery efforts
- Inventory, monitoring and protection of these wetlands are priorities

Aside from these PMAs, there are many other wetland areas in the Lake Huron basin that provide significant fisheries benefits at a local or regional level. Examples are: Thunder Bay, Misery Bay, Bell Bay, and Thompson Harbor, all between Alpena and Rogers City, and the Fishing Islands on the Bruce Peninsula. These areas should not be overlooked as they all contribute to the overall productivity and resiliency of the Lake Huron aquatic ecosystem.

The significance of these PMAs has also been identified through other initiatives including the State of the Lake Ecosystem Conference '96 (SOLEC), sponsored by the United States Environmental Protection Agency (USEPA) and Environment Canada (EC) as well as the Lake Huron Initiative (LHI) sponsored by the Office of the Great Lakes, Michigan Department of Environmental Quality. The concept of Biodiversity Investment Areas (BIA), was introduced at SOLEC 96 in order to recognize areas with exceptionally high ecological values which warrant exceptional attention to protect them from degradation. The PMAs identified in this EO were also designated as BIAs for the Lake Huron basin.

Information and research needs:

The following is a list of information and research needs as they relate to this Environmental Objective:

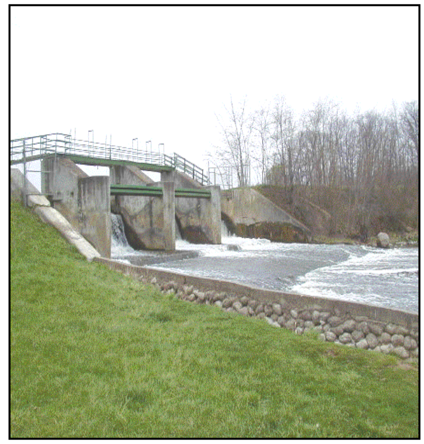
- Establish the link between fish production/diversity and coastal wetland health/function
- A coastal wetland inventory for Lake Huron for both U.S. and Canadian waters of the basin is needed
- Develop, implement and evaluate rapid assessment techniques for quantifying wetland area and quality using satellite imagery
- Monitor the role of water levels on coastal wetland integrity
- Monitor exotic species affects on coastal wetland form and function
- Establish a standardized program for monitoring and assessing coastal wetlands and associated fish community structure over time in key or index wetland sites
- Develop education material that highlights the cyclical nature of Great Lakes coastal wetlands and the need to protect these areas from incremental development

Policy needs:

- A comprehensive lake-wide policy on the growing allowance and permitting of beach and bottomland vegetation removal and grooming by private landowners.

1.2 Spawning and nursery habitats (tributaries)

Protect and restore connectivity and functionality of <u>tributary</u> spawning and nursery areas throughout the Lake Huron Basin



Relevance to Fish Community Objectives:

Fish Community Objectives	Importance of Environmental Objective
Establish a diverse salmonine community that can sustain an annual harvest of 2.2 million kg with lake trout the dominant species and anadromous (stream-spawning) species also having a prominent place.	*Rainbow trout, chinook salmon, coho salmon, and Atlantic salmon are dependent on access to rivers and streams for spawning and nursery habitats throughout the Lake Huron basin. The most productive watersheds are located in southern Georgian Bay, southern Manitoulin Island, the east shore of the main basin and the tributaries and rapids of the St. Marys River.*
Increase the abundance of lake sturgeon to the extent that the species is removed from its threatened status in United States waters. *Maintain or rehabilitate populations in Canadian waters*	*Lake sturgeon depend on access to spawning habitat in larger rivers draining into the Lake Huron basin. Important rivers are the St. Clair River outlet of Lake Huron and tributaries to south-eastern Georgian Bay, the north shore of the North Channel, the St. Marys River and the larger rivers draining into the main basin from Thunder Bay to Saginaw Bay.*
Reduce sea lamprey abundance to allow the achievement of other fish community objectives.	*Sea lamprey utilize rivers and streams of all sizes for spawning and nursery habitat throughout the Lake Huron basin. The St. Marys River is the largest producer of sea lampreys in the Great Lakes Basin.*
Re-establish and/or maintain walleye as the dominant cool-water predator over its traditional range with populations capable of sustaining a harvest of 0.7 million kg. *Maintain yellow perch as the dominant nearshore omnivore while sustaining a harvestable annual surplus of 0.5 million kg.*	*A majority of walleye populations throughout the Lake Huron basin are dependant on access to spawning habitats found in rivers and streams. Critical spawning rivers are found in Saginaw Bay, the St. Marys River, the north shore of the North Channel and eastern Georgian Bay. Yellow perch ascend small, warm water tributaries (sloughs) especially in Saginaw Bay to spawn.*

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Maintain northern pike as a prominent predator throughout its natural range *Maintain muskellunge in numbers and at sizes that will safeguard and enhance its special status and appeal*	*Northern pike and to a lesser extent muskellunge require access to riverine wetlands for spawning and nursery habitats throughout the Lake Huron basin.*
Sustain smallmouth and largemouth bass and the remaining assemblage of sunfishes at recreationally attractive levels over their natural range.	*Smallmouth bass and to a lesser extent other centrarchids will utilize spawning and nursery habitats in lower reaches of rivers when they are accessible throughout the Lake Huron basin.*
Maintain Channel catfish as a prominent predator throughout its natural range while sustaining a harvestable annual surplus of 0.2 million kg.	*Channel catfish spawn in larger rivers throughout the Lake Huron basin and use these locations as feeding areas.*
Maintain a diversity of prey species at population levels matched to primary production and to predator demands.	*Both native and non-native prey fish will use river and stream spawning and nursery habitats throughout the Lake Huron basin. The St. Marys River is one of Lake Huron's most important spawning sites for lake herring.*
Recognize and protect the array of other indigenous fish species because they contribute to the richness of the fish community. These fish- cyprinids, rare ciscoes, suckers , burbot, gar, and sculpins- are important because of their ecological significance; intrinsic value; and social, cultural, and economic benefits.	*A variety of sucker species, freshwater drum, white bass, and burbot are highly dependant on access to river and stream spawning habitats throughout the Lake Huron basin.*
Maintain and promote genetic diversity by conserving locally adapted strains. *Ensure that strains of fish being stocked are matched to the environments they are to inhabit.*	*Many fish species in the Lake Huron basin have the ability to home to specific spawning locations, many of which are located in watersheds draining into the basin. If access to these areas is impeded, the loss of these locally adapted populations and overall genetic diversity may be the result.*
Protect and enhance fish habitat and rehabilitate degraded habitats. *Achieve no net loss of the productive capacity of habitat supporting Lake Huron fish communities and restore damaged habitats.* *Support the reduction or elimination of contaminants.*	*Rivers and streams are some of the most altered and disrupted habitats in the Lake Huron basin. Many of the watersheds draining into Lake Huron have barriers to upstream access and have flow regimes that have been altered as a result of watershed land-use changes or hydro-electric generation needs. Nonpoint pollution, particularly agricultural nutrients and soil sediment, are major causes of degradation of watersheds in more developed basins of Lake Huron.*

Background:

The Lake Huron watershed is one of the largest in the Great Lakes draining an area greater than 134,000 km² (Herdendorf 1990). Numerous large river systems as well as many smaller tributaries drain into the basin. In U.S. waters, over 10,000 km of tributary habitat were at one time accessible to fish of Lake Huron (Gebhardt et al. 2003). With ⅔ of the Lake Huron watershed being located in Canadian waters it is likely that an even greater amount of tributary habitat was available on the Canadian side. These watersheds, as well as connecting channels like the St. Marys River, serve as vital spawning, nursery and feeding areas for a variety of species found in the Lake Huron basin.

Tributary habitats throughout the Great Lakes are important areas of fish production and diversity. The principal spawning and nursery habitats for ⅓ of the fishes in the Great Lakes are located in tributaries (Lane et al. 1996). Most walleye populations in Lake Huron are closely associated with tributaries draining into the basin (Spangler et al. 1977; Schneider and Leach 1979; Reckahn and Thurston 1991; Mrozinski et al. 1991). Lake Sturgeon historically used spawning areas located in the larger rivers draining into the Lake Huron basin (Ono et al. 1983; Rochard et al. 1990). The naturalization of Pacific salmonids and, in particular, rainbow trout and Chinook salmon have come about as the result of access to spawning and nursery habitats found in tributary ecosystems throughout the Lake Huron basin (Macrimmom and Gots 1972; Biette et al. 1981; Johnson et al 1995; Woldt et al 2003). Some now extirpated lake trout stocks of Lake Huron probably spawned in tributaries.

Maintaining, protecting and restoring the accessibility and function of tributary habitats throughout the Lake Huron basin will ensure that critical spawning, nursery and feeding habitats are available for salmonids, percids, esocids, ictalurids, catastomids, sturgeon and a variety of prey fishes. Accessible and functioning tributary habitats will also contribute to overall genetic diversity of fish species and assist in preserving rare and provincially significant species that add to the biological diversity in the Lake Huron basin.

Description of issues:

Rivers and streams are some of the most altered and disrupted habitats in the Lake Huron basin. The construction of canals, locks, hydropower and other dams and water-level control structures have restricted fish access and altered flows and temperatures in tributaries and connecting channels throughout the Great Lakes (Edsall and Charlton 1997). The loss of fish populations through river fragmentation and significant reductions in abundance due to barriers is well documented (Porto et al. 1999; Jager et al. 2001). The construction of hydropower dams reached its peak in the early 20th Century; few of these dams have effective fish ladders or devices that allow fish to pass over dams unharmed (Edsall and Charles 1997). In addition, these facilities seriously altered natural flow regimes and replaced them with ‘peaking’ flows, increasing flow rates when power demand is high, and reducing them when demand is low. These changes have resulted in increased scouring and extreme flow and temperature changes. Most dams that release surface water cause significant warming of their tailwaters, often to the detriment of salmonid fish.

The alteration of tributary habitats in the Lake Huron basin had a profound impact on a number of fish species. The lake sturgeon was historically a much more prominent nearshore benthivore than presently, accounting for over 1.8 million kg in commercial harvest in the late 1800s (Hay-

Chmielewski and Whelan 1997). At least 34 tributaries distributed throughout the three major basins of Lake Huron historically supported spawning populations (Zollweg et al. 2003). Currently, access to most of these historic spawning habitats is blocked by dams. The continued decline in lake sturgeon abundance in many parts of the basin has been attributed in part to the presence of barriers on historic spawning tributaries (Ono et al. 1983; Rochard et al. 1990) and altered flow patterns below dams (Auer 1996).

The abundance and diversity of walleye populations in the Lake Huron basin have declined due to tributary degradation and impoundment. Historically, tributary habitats were negatively impacted by activities such as timber harvest, logging drives and mining that resulted in the deposition of bark, silt, contaminants and gross habitat change during the 20th Century (Collins 1988). The presence of barriers and altered flow regimes on many tributaries continues to be a major impediment to this day. Dams and spillways continue to impede spawning migrations of walleye in Saginaw Bay, as a result, natural reproduction is limited and the population is highly dependant on stocking (Fielder 2002; Fielder et al. 2003). Walleye abundance throughout eastern Georgian Bay and the North Channel of Lake Huron remains low compared to historic levels in part due to altered access and flow regimes on tributaries (Reckhan and Thurston 1991).

Anadromous salmonids are a prominent component of the fish community in Lake Huron as a result of an ambitious stocking program (Kocik and Jones 1999; Woldt et al. 2003, Whalen and Johnson 2004). Until recently, at least, stream spawning salmonids were dependent on hatchery production because of low reproduction rates in Lake Huron's tributaries. Consequently, over 253,000,000 salmonids, mostly composed of tributary spawning species, have been stocked into Lake Huron since 1963, at a cost of nearly $50,000,000 (Whelan and Johnson 2004). Rainbow trout (steelhead) became naturalized early in the 20th century (Macrimmom and Gots 1972; Biette et al. 1981). Pink salmon became naturalized in the 1980s. Since 1999, more then ¾ of Chinook salmon harvested in Lake Huron's summer troll recreational fishery were from natural reproduction (Lake Huron Technical Committee, unpublished data), suggesting this species is becoming less hatchery dependent. Natural recruitment of salmonids in the Lake Huron basin is quite variable and is subject to annual differences in discharge conditions and accessibility of coldwater tributary habitat. Most cold water tributaries draining into U.S. waters of Lake Huron are inaccessible due to barriers (Seelbach et al. 1997; Gebhardt et al 2003), thus limiting their anadromous salmonid production (Johnson et al. 1995). In Ontario waters, cold water tributaries are more abundant and although access to some upper watershed spawning locations is restricted, most of the larger tributaries have functional fishways (Gonder In Press).

Many other fish species inhabiting Lake Huron utilize tributary habitats. Historically 79 species were found in Lake Huron with an additional 50 residing within tributaries (Bailey and Smith 1981). As a result of tributary degradation through watershed development or barrier construction, many of these species were extirpated or are imperiled (Hubbs and Lagler 1964; Jenkins 1988; Master 1991). The decline in abundance of species such as river redhorse, river darter, black redhorse, redside dace, eastern sand darter, and channel darter due to loss of stream habitat (Schaeffer and Woldt 2003) has a negative impact on maintaining biodiversity in the Lake Huron basin.

Improving fish passage in tributaries has been identified as a high priority by resource agencies on Lake Huron (Ebener 2003). In addition, the Fish community Objectives for Lake Huron stress the need for restoring fragmented and degraded streams and stream-influenced habitat as a key for bolstering populations of salmonines, percids, esocids and lake sturgeon (DesJardine et al. 1995). Although the benefits of improving fish passage to tributaries is well established there are many challenges associated with this pursuit. Some of these challenges relate to prioritizing the selection of barriers to remove, designing fishways that effectively pass a variety of species, avoiding the negative impacts of interspecific competition with increased upstream access, and determining the impact that increased access to tributary habitat will have on lamprey abundance.

While fish passage by ladders is better than no improvement, dam removal is the preferred option. Full removal of dams eliminates issues of safe transport of adults and juveniles back downstream to Lake Huron. Dams also typically impound the reaches of river that are highest in gradient which usually forms the best spawning habitat. The partial dependence on barriers for sea lamprey control is likely to be the most challenging on Lake Huron which currently supports the largest population of sea lamprey in the Great Lakes (Morse and Young 2003). There are 17 barriers constructed on Lake Huron tributaries that block lamprey from over 450 kilometers of high quality riverine habitat. Recovery of native fish populations requiring access to tributary habitats throughout the basin is highly dependant on resolving this issue.

Summary of current and historic data:

Information on the distribution, quality and accessibility of tributary habitats in the Lake Huron basin is quite variable and in many cases incomplete. Michigan maintains an ecological classification system of river valley segments for major tributaries draining into the Lake Huron basin (Seelbach et al. 1997). This system has provided insights on the hydrology, temperature and gradients of river systems which will be useful in establishing the fish production potential of numerous watersheds. The Michigan Department of Environmental Quality (MDEQ) has also recently identified and characterized over 800 barriers on Michigan tributaries (Gebhardt et al. 2003). This exercise has revealed that 86% of major tributaries are no longer connected to the Lake Huron basin (Gebhardt et al. 2003). The extent to which dams have isolated tributary habitat from the anadromous species of Lake Huron is significant (Table 1).

Numerous examples exist illustrating the large potential that increased access through barrier removal or fish passage can have on fish production for the Lake Huron basin. The Au Sable River situated in lower Michigan, is a large (5,000 km^2) watershed that contains the largest amount of big-river, high-gradient habitat in the southern part of the state (Zorn and Sandeck 2001). Only 13 km of an estimated 250 km of mainstem river are currently accessible due to barriers on the watershed. The Thunder Bay River once supplied ample sturgeon spawning habitat in the form of 3-7 m per km gradient cataracts within 2 km of Lake Huron. Presently, 1 km of low gradient habitat is accessible due to a complex of hydroelectric dams. In the Saginaw Bay's watershed, 72% of river reaches are inaccessible to fish migrating from the bay (Fielder and Baker In Press). Substantial benefits from improved fish passage in the Saginaw River watershed have been identified with the selection of numerous candidate dams for removal or construction of fishways (Fielder and Baker In Press).

A spatially explicit classification and inventory of tributary habitats in Ontario waters of Lake Huron, similar to that conducted in Michigan, is still in progress (Les Stanfield, Ontario Ministry of Natural Resources, personal communication). Tributary attribute information was collected primarily from watersheds situated in Southern Georgian Bay and central and southern main basin of Lake Huron. In addition, a recent initiative by the Nature Conservancy of Canada and the Ontario Ministry of Natural Resources has produced an Aquatic Ecological Land Classification for Ontario Great Lakes watersheds (Wichart 2003). This classification system provides an objective assessment of watershed quality and identifies priority areas for research, management and protection.

In a few instances where provincial conservation authorities are established, more detailed watershed information is available. The Nottawasaga River, a relatively large (3,330 km^2) drainage basin with few barriers provides access to over 620 km of riverine habitat, of which 100 km is characterized as high quality spawning habitat and 400 km is classed as nursery habitat for a variety of fish species (Fred Dobbs, Nottawasaga Valley Conservation Authority, personal communication). Information on natural and artificial barriers to fish movement in watersheds draining into the Canadian waters of the Lake Huron basin is currently being compiled.

Fisheries assessment data from many watersheds is fragmented and incomplete. Recent summaries on the status of walleye populations from the Saginaw Bay watershed (Fielder and Baker In Press), St. Marys River (Gebhardt 2000; Fielder et al. In Press) and eastern Georgian Bay and the North Channel (Liskauskas 2002) have been completed. The USFWS, OMNR, MDNR plus other agencies, academic institutions and First Nations have coordinated efforts to compile information on Lake Huron sturgeon stocks since 1995. These ongoing efforts have confirmed sturgeon spawning sites throughout the basin and continue to investigate additional tributaries for lake sturgeon recruitment (Zollweg et al. 2003). The distribution and relative status of rainbow trout populations throughout the Canadian waters of Lake Huron has also been recently summarized (Gonder In Press).

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Priority areas and issues:

For the Lake Huron basin to achieve its full potential for fish production, lost connectivity with watersheds draining into the basin needs to be re-established. This is particularly true for the larger river systems that historically contributed significant fish production for a diversity of species in the Lake Huron basin. Along with connectivity, the unaltered temperatures, water quality, and hydrological flow regimes of these watersheds are important to maximize the utility of these watersheds for spawning, nursery and feeding purposes. Although all watersheds contribute or have the potential to contribute fish production, some watersheds due to their size, location and habitat characteristics should be considered priority watersheds.

The following is a list of Priority Management Areas (PMAs) and some of their attributes:

Saginaw Bay watershed

- Historically supplied with tributary spawning habitat for a variety of species, most importantly walleyes and lake sturgeon
- Fish access to upper watershed is restricted due to dam construction
- Evidence of walleye recruitment in lower reaches of Flint and Tittabawassee rivers
- Opportunities exist for selected barrier removal or construction of fish passage

St. Marys River

- Historically river rapids provided spawning habitat for a variety of species (lake herring, sturgeon, walleyes)
- Currently rapid spawning habitat reduced but still productive
- Currently provides spawning habitat for a variety of salmonid species (rainbow trout, chinook salmon, coho salmon, Atlantic Salmon)
- Opportunities to expand fish spawning potential through flow and channel modification
- Effects of peaking and ponding for hydropower production is poorly understood
- Supports largest population of sea lamprey in the Great Lakes

Garden River, Mississagi River and Spanish River

- Historically provided accessible spawning habitat for a variety of species (walleye, sturgeon)
- Currently are significant watersheds for sturgeon, walleye, Chinook salmon, and pink salmon production
- Mississagi and Spanish Rivers currently under review for a water management plan
- Maintaining and improving fish access to these tributaries is a priority

Moon River and Severn River

- Historically provided spawning habitat for a variety of species (walleye, sturgeon, muskellunge)
- Currently spawning areas impacted by low or variable flow regimes that do not maximize reproductive potential

- Significant gains in spawning habitat utilization and productivity can be achieved with flow and channel modifications
- Moon River part of the Muskoka River Water Management Planning initiative

Nottawasaga River

- Historically an important watershed for providing spawning and nursery habitat for a variety of species (walleyes, sturgeon, rainbow trout)
- One of the least obstructed watersheds in the Lake Huron basin
- Important spawning habitat for a variety of salmonids (rainbow trout, Chinook salmon) and sturgeon
- Access to additional spawning habitat can be enhanced through selective barrier removal

Saugeen River

- Historically an important watershed for providing spawning and nursery habitat for a variety of species (sturgeon, rainbow trout, muskellunge, walleyes, channel catfish, suckers)
- Downstream fishway constructed for sea lamprey control and passage of salmonids
- Additional mainstem barriers exist in the form of hydro generating dam and milldams
- Opportunities for barrier removal or modification to allow access to other fish species should be pursued

Au Sable River and Thunder Bay River

- Historically important watersheds providing spawning habitat for a variety of species (sturgeon, walleye, esocids)
- Current barriers restrict access to high gradient spawning and nursery habitats
- Some rare high gradient reaches are impounded in the Thunder Bay River
- Due their large size, the potential benefits through selective barrier removal would be immense

Information and research needs:

The following is a list of information and research needs as they relate to this Environmental Objective:

- Complete inventory of location and attributes of all barriers in the watershed
- Determine number of barriers in priority management areas
- Identify candidate dam removal/ fishway installation locations by watershed
- Quantify the gain of spawning and nursery habitat through barrier removal as well as potential production potential
- Establish ‘run of river’ (natural hydrograph) flows below hydroelectric dams to maximize spawning habitat utilization by species
- Encourage research/development of methods for passing non-jumping species such as lake sturgeon and walleyes

- Establish the cumulative fish production from minor watersheds throughout the basin.
- Determine the origin of naturally recruited Chinook salmon and walleye through isotope signatures
- Complete stream classification for all watersheds draining into the Lake Huron basin
- Complete ground truthing of spawning site models for walleyes, lake sturgeon, rainbow trout, and Chinook salmon

Policy needs:

- Develop lakewide policy for dams, dam removals and priorities, and dam retirement funding approaches, and the establishment of new barriers including those intended for sea lamprey control.
- Identify critical tributary reaches for restoration
- Work with agriculture agencies to identify means of reducing impact of sedimentation and nitrification on fish communities and water quality
- Improve enforcement of stream protection regulations

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Table 1. Kilometers of major tributary habitats in Michigan historically and presently connected to Lake Huron stratified by catchment size, reach gradient, and July mean temperature conditions. Only tributaries more than roughly 15 km in total length are included in this analysis. (Taken from Gebhardt et al. 2003).

	Historic					**Present**			
	Gradient class					Gradient class			
Size class	Very Low	Low	Moderate	High	Size class	Very Low	Low	Moderate	High
Coldwater									
Small	41	336	201	0	Small	10	15	0	0
Medium	320	517	347	8	Medium	0	19	1	8
Large	8	22	0	0	Large	0	0	0	0
Very Large	0	37	0	0	Very Large	0	0	0	0
Coolwater									
Small	344	451	127	0	Small	50	84	102	0
Medium	512	559	43		Medium	18	113	43	0
Large	92	135	0	0	Large	38	29	0	0
Very Large	69	50	67	0	Very Large	17	46	0	0
Warmwater									
Small	1223	168	0	0	Small	196	7	0	0
Medium	361	192	0	0	Medium	78	34	0	0
Large	20	115	0	0	Large	0	0	0	0
Very Large	602	43	17	0	Very Large	219	0	6	0

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1.3 Spawning and nursery habitats (reefs)

Protect and restore reef spawning areas throughout the Lake Huron Basin

Relevance to Fish Community Objectives:

Fish Community Objectives	**Importance of Environmental Objective**
Establish a diverse salmonine community that can sustain an annual harvest of 2.2 million kg with lake trout the dominant species and anadromous (stream-spawning) species also having a prominent place.	*Lake trout utilize spawning reefs comprised of cobble and boulder substrates that are free of excessive algae or fine sediments. Although spawning reefs are found throughout the basin, concentrations are found along the south shore of Manitoulin and Drummond Island, the Bruce Peninsula, east shore of Georgian Bay, Thunder Bay, Straits of Mackinaw area, and the Six Fathom Bank/Yankee Reef complex in the main basin*
Maintain the present diversity of coregonines. *Manage lake whitefish and ciscoes at levels capable of sustaining annual harvests of 3.8 million kg.* *Restore lake herring to a significant level and protect, where possible, rare deepwater ciscoes.*	*Spawning reefs for lake whitefish are found throughout the Lake Huron basin with concentrations found around Manitoulin Island, the north shore of the North Channel, the Thunder Bay area, the west shore of the Bruce peninsula and southern Georgian Bay. Lake herring spawning areas consisting of clean gravel substrates were historically found throughout the nearshore areas of the entire Lake Huron basin, but particularly those in Saginaw Bay.*
Re-establish and/or maintain walleye as the dominant cool-water predator over its traditional range with populations capable of sustaining a harvest of 0.7 million kg. *Maintain yellow perch as the dominant nearshore omnivore while sustaining a harvestable annual surplus of 0.5 million kg.*	*Historically, numerous shoal or reef spawning populations of walleye could be found throughout the Lake Huron basin. The most significant walleye populations utilizing these spawning habitats were found in the Saginaw Bay area. Other reef spawning populations of walleye could be found in eastern Georgian Bay and the north shore of the North Channel*

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Protect and enhance fish habitat and rehabilitate degraded habitats. *Achieve no net loss of the productive capacity of habitat supporting Lake Huron fish communities and restore damaged habitats.* *Support the reduction or elimination of contaminants.*	*Nearshore and offshore reefs are one of the most common habitat features throughout the Lake Huron basin. For the most part these habitats have not been physically altered to the extent that other habitat types have; however, the colonization of these habitats by exotic species has accelerated in recent years and may in time degrade the quality of these habitats. Reef habitat of Saginaw Bay, however, has suffered degradation from sediments resulting from land-use practices in the watershed.*

Background:

Lake Huron is a deep oligotrophic lake, with a mean depth of 59 m and depths greater than 30 m over two-thirds of its surface (Berst and Spangler 1973). The lake's fish community has been historically dominated by deep-dwelling species such as lake trout and ciscoes. Most of these species utilize offshore or nearshore reefs for spawning purposes. The widespread availability of such habitat features had a major influence on structuring the resident fish community. Specifically, the widespread distribution of reef habitats suitable as spawning habitat has contributed to the diversity of lake trout (Burnham-Curtis 1993; Eshenroder et al. 1995), lake whitefish, and walleye populations.

The Lake Huron basin has a complicated geology which reflects a long history of glacial advances and retreats (Hough 1958). A number of geological formations such as the Silurian dolomite comprising the Niagara Escarpment (Hough 1958) and found along the north shore of the main basin, Manitoulin Island and the Bruce Peninsula, as well as the Bois Blanc (Devonian) which includes reefs southeast of the Straits of Mackinac, Bois Blanc Island, Spectacle Reef, Thunder Bay, and Six-Fathom Bank, have been identified as important lake trout spawning areas (Eshenroder et al. 1995). Glacial and bedrock till are widespread in the Georgian Bay and North Channel areas (Thomas 1988) providing additional spawning habitat for both lake trout and coregonid species.

A variety of fish species in the Lake Huron basin utilize reef habitats for spawning purposes. Nearshore or shallow reefs (<30 m) are principally utilized by lake trout and lake whitefish (Goodyear 1982) and to a lesser extent walleye (Schneider and Leach 1977; Reckahn and Thurston 1991). A limited number of species have been identified as utilizing deep, offshore reefs among them being lake trout, five species of cisco and fourhorn sculpin (*Myxocephalus quadricornis*) (Goodyear 1982). Only lake trout spawn in both the shallow nearshore waters and also the deeper offshore waters (Goodyear 1982).

Maintaining, protecting and restoring the function of reefs throughout the Lake Huron basin will ensure that critical spawning habitat is available for lake trout, lake whitefish and walleyes.

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Description of issues:

Offshore habitat in the Lake Huron basin remains relatively unchanged from historic times and should provide ample high quality habitat for lake trout, whitefish and ciscoes (Ebener et al. 1995). Reefs in nearshore areas, however, are vulnerable to a variety of factors not affecting offshore reefs, such as groundwater intrusion, lake level changes, navigation and channelization, and a variety of shoreline stresses associated with development and land-use practices (Sly and Busch 1992). For some species such as lake whitefish, good to excellent year classes were produced throughout the lake in recent years suggesting that their favored nearshore spawning reefs are not significantly degraded (Ebener et al. 1995).

For some reef spawners such as walleyes, there exists documented evidence of reef degradation (Fielder 2002). In Saginaw Bay, offshore reefs were a historically important source of walleye reproduction (Schneider and Leach 1977). As a result of human activities in the Saginaw River watershed, increased sedimentation and eutrophication has degraded reef spawning habitat in Saginaw Bay to the point where it no longer is a significant source of walleye recruitment (Schneider and Leach 1977; Keller et al. 1987; Fielder 2002).

The proliferation of exotic species in the Lake Huron basin may pose some of the most serious threats to the integrity of both nearshore and offshore spawning reefs. Alewives and rainbow smelt have long been implicated in reducing recruitment from reef spawning areas due to their predation on larval fish (Smith 1970; Brown et al 1987) and lake trout fry (Krueger et al 1995; Johnson and Van Amberg 1995). The more recent colonization of hard lake substrates including reefs by zebra (*Dreissena polymorpha*) and Quagga (*Dreissena bugensis*) mussels in the Lake Huron basin (Nalepa and Tuchman 2000) has the potential to further compromise the integrity of these spawning habitats. There is also a growing concern that reef spawning species such as walleye, lake whitefish, and lake trout may be negatively impacted from egg predation by expanding populations of round goby (*Neogobius melanostomus*) (Jude 1996; Chotkowski and Marsden 1999).

The potential for cultural eutrophication of spawning reefs in Canadian waters of Lake Huron has increased in recent years with the advent of cage aquaculture. This industry which utilizes floating cages to raise rainbow trout in open waters has expanded from 20 cages in the mid-1980s to over 100 by the late 1990s (Gale 1999). These operations are concentrated at the east end of the North Channel though two are located in Georgian Bay. Currently, the level of production is approximately 3.0 million kg, or roughly the equivalent of the total Ontario commercial fishery for all species, with an estimated discharge of 15,000 t of phosphorous, 90 t of nitrogen and 500 t of solid waste per year (Gale 1999). The selection of suitable operating sites and methods for reducing nutrient waste will be important areas of future inquiry. Increasing recreational boating, cottaging and urban development throughout the Lake Huron basin also have the potential to increase nutrient loading and impact reef habitats.

In areas where reef habitats have been degraded or where habitat diversity is low, there has been a growing interest in determining whether artificial reefs can have a positive impact on fish production. In the Great Lakes, a review of artificial reefs as a fishery management technique (Ganon 1990), concluded that the benefits of artificial reefs remain unproven and that long-term evaluation of existing and future reef projects is recommended. Few artificial reefs have been built in the Lake Huron basin and none have been objectively evaluated with respect to their value as spawning habitat. The benefits of an artificial reef in the Tawas Bay portion of Saginaw Bay, has not been clear (Fielder 2002). Fielder and Baker (In Press) call for experimental demonstration projects on reef reclamation in Saginaw Bay. They distinguish reef reclamation from artificial reefs where the former has emphasis on recovery of historic reef habitat and is limited to natural materials such as rock cobble and gravel as opposed to man-made construction debris or other artificial materials. The future efficacy of artificial reefs or reef reclamation in Lake Huron has yet to be fully determined.

Summary of current and historic data:

Information on the distribution and characterization of reef habitats throughout the Lake Huron basin is incomplete and in many cases dated. A review of historical commercial catch data for lake trout in U.S. waters revealed that a majority of the historic lake trout spawning habitat is located in northern and north-central Lake Huron (Eshenroder et al. 1995; Ebener 1998). A total of 48 specific spawning reefs were identified based upon commercial catches from 1929-32 (Eshenroder et al. 1995). Only a few of these sites have undergone detailed assessments.

Underwater observations of bottom substrates have occurred at 12 spawning grounds formerly used by lake trout in western Lake Huron (Nester and Poe 1987). Further detailed surveys of spawning reefs using side-scan sonar and underwater video have been undertaken at Mischley Reef near Thunder Bay (Edsall and Kennedy 1995), Port Austin Reef at the mouth of Saginaw Bay (Edsall et al. 1992a) and Six Fathom Bank-Yankee Reef (Edsall et al. 1992b) in central Lake Huron. All of these sites were characterized as having high quality substrates for lake trout reproduction.

In Canadian waters detailed spawning reef assessments are absent. Smith (1968) compiled a summary of information on lake trout spawning areas obtained from interviews conducted with commercial fisherman. Although anecdotal, this summary provides an indication of how widespread and abundant historical spawning reefs were in this part of the basin. Based on these interviews, over 100,000 ha of spawning reefs were identified with approximately 54,000 ha in the main basin of Lake Huron, 43,000 ha in Georgian Bay and 11,000 ha in the North Channel. In Parry Sound, where one of only two native lake trout strains survived in the Lake Huron basin, natural recruitment in recent years has contributed to the rehabilitation of this population (Reid et al. 2001). As is the case for other locations where natural recruitment of lake trout has occurred in Canadian waters, no detailed assessment of reef characteristics exists.

A similar summary for lake whitefish spawning reefs using interviews with commercial fisherman (Loftus 1980) and larval fish studies (Loftus 1977, 1979), revealed the widespread distribution of this type of habitat (Mohr and Loftus in progress). The most extensive areas of whitefish spawning habitat were found along the west side of the Bruce Peninsula, in the Blind River-Thessalon area of the North Channel, along the south shore of Manitoulin Island and in southern and northeast Georgian Bay. Some of the southern Georgian Bay spawning locations where also inferred from whitefish tag-recapture studies conducted in the area (Cucin and Regier 1965). Most reefs were located close to shore in 1-6 m of water however a few offshore sites were also identified including the Western Islands, Halfmoon Island and Dawson Rock (Mohr and Loftus in progress).

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Most of the reefs in the inner portion of Saginaw Bay are degraded as a result of sedimentation (Fielder 2002). There is still considerable reef habitat in the outer portion of the bay but that is thought to be too cold in the spring to attract spawning walleye. Fielder (2002) developed inspection, sampling, and mapping techniques for reef habitat in Saginaw Bay.

The Lake Huron GIS project, by assimilating these and other sources of information, mapped the general locations of both lake trout and lake whitefish spawning sites. An impediment to refining the locations, extent, and potential quality of these reefs is lack of a spatially explicit inventory of the surficial geology of the Lake Huron lake bed.

Priority areas and issues:

The distribution of reef spawning habitat is extensive throughout the Lake Huron basin and is utilized by a variety of species. Historical degradation of reefs has been minimal and localized. Reef habitat quality is compromised in areas that have experienced urbanization and land-use changes. Further deterioration of reef functions may be caused by the colonization of exotic species such as zebra mussels, round goby and ruffe.

The following is a list of Priority Management Areas (PMAs) and some of their attributes:

Saginaw Bay

- Extensive reef complexes historically important for walleye, lake whitefish and lake herring reproduction
- Extensive sedimentation has resulted in loss and degradation of existing reefs.
- Opportunities exist for implementing experimental approach to reef reclamation
- Abundance of exotic species in reef areas

Manitoulin Island

- High density of spawning reefs surrounding the island
- Presumed whitefish recruitment in recent years
- The north and northeast shores are being used for cage aquaculture
- Impact of increased nutrient loading may degrade reef quality
- Detailed reef characterization and mapping required

Western shore of Bruce Peninsula (including Fishing Islands complex)

- High concentration of lake trout and lake whitefish spawning reefs
- Presumed whitefish recruitment in recent years
- Detailed reef characterization and mapping required

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Georgian Bay

- Extensive reef complexes throughout
- Impact of zebra mussel colonization and round goby expansion needs to be monitored
- Lake trout reproduction in Parry Sound, Iroquois Bay, South Bay and Owen Sound
- Detailed reef characterization and mapping required

Thunder Bay

- Extensive reef complex
- Presumed whitefish recruitment in recent years
- Recent evidence of successful lake trout reproduction
- Impact of ruffe and round goby colonization needs to be determined

Drummond Island and Mackinaw Island

- Extensive reef complex
- Presumed whitefish recruitment in recent years
- Historically important area for lake trout reproduction
- Detailed reef characterization and mapping required

Six Fathom Bank and Yankee Reef

- Large, offshore reef complex
- Recent evidence of lake trout recruitment
- Ongoing monitoring required to determine impact of exotic species

Information and Research needs:

The following is a list of information and research needs as they relate to this Environmental Objective:

- The continued expansion of exotic species in the Lake Huron basin will require more intense monitoring to determine their impact on reef function and quality, with emphasis on survival of early life stages of native species
- The rehabilitation of degraded reefs or the creation of new reefs is an area requiring further inquiry
- the advent of cage aquaculture in the Manitoulin Island area of Lake Huron may require that reefs in the area be monitored for cultural eutrophication
- reef assessments are also needed in areas experiencing increased recreational development such as eastern Georgian Bay

- An inventory and characterization of reef habitats throughout the basin needs to be undertaken as well as a selection of representative sites for more intensive monitoring through time
- Spatially explicit measurement and mapping of the surficial geology of the lake bed would enable more precise measurement and classification of reef habitats.

2. Shoreline Processes

Protect and rehabilitate nearshore habitats and reestablish the beneficial structuring forces of natural water exchanges, circulation, and flow that they provide.

Relevance to Fish Community Objectives:

Fish Community Objectives	Importance of Environmental Objective
Establish a diverse salmonine community that can sustain an annual harvest of 2.2 million kg with lake trout the dominant species and anadromous (stream-spawning) species also having a prominent place.	*All salmonids utilize nearshore habitats to some extent for spawning, nursery and feeding purposes. YOY Chinook and rainbow trout are often found in sandy beach zones shortly after they leave their natal streams and rivers.*
Maintain the present diversity of coregonines. *Manage lake whitefish and ciscoes at levels capable of sustaining annual harvests of 3.8 million kg.* *Restore lake herring to a significant level and protect, where possible, rare deepwater ciscoes.*	*Large contiguous shorelines with sandy depositional zones are frequented by the early life-history stages of many coregonid species. Lake herring spawning areas are distributed throughout the Lake Huron nearshore zone across a variety of substrates ranging from sand to gravel.*
Increase the abundance of lake sturgeon to the extent that the species is removed from its threatened status in United States waters. *Maintain or rehabilitate populations in Canadian waters*	*Lake Sturgeon adults and juveniles utilize nearshore feeding zones.*
Re-establish and/or maintain walleye as the dominant cool-water predator over its traditional range with populations capable of sustaining a harvest of 0.7 million kg. *Maintain yellow perch as the dominant nearshore omnivore while sustaining a harvestable annual surplus of 0.5 million kg.*	*Walleye and yellow perch utilize nearshore areas throughout their life-cycle, with larval and juvenile walleye found in shallow, sheltered embayments for feeding and protection, and adults utilize these areas for feeding.*
Maintain northern pike as a prominent predator throughout its natural range *Maintain muskellunge in numbers and at sizes that will safeguard and enhance its special status and appeal*	*Northern pike and muskellunge utilize the nearshore for preferred feeding areas.*

Sustain smallmouth and largemouth bass and the remaining assemblage of sunfishes at recreationally attractive levels over their natural range.	*Smallmouth bass and other centrarchids rely on nearshore areas for all life-history stages including spawning and nursery habitats to adult feeding areas. Clean cobble and boulder, sheltered shorelines are used by smallmouth bass and can be found in abundance along the eastern shore of Georgian Bay, the west shore of the Bruce Peninsula, Saginaw Bay, Les Cheneaux Islands, and Thunder Bay.*
Maintain Channel catfish as a prominent predator throughout its natural range while sustaining a harvestable annual surplus of 0.2 million kg.	*Channel catfish feeding areas are located in nearshore areas.*
Maintain a diversity of prey species at population levels matched to primary production and to predator demands.	*Prey species utilize nearshore habitats for all life-history stages. The beach zone hosts Lake Huron's greatest diversity of fish species.*
Recognize and protect the array of other indigenous fish species because they contribute to the richness of the fish community. These fish- cyprinids, rare ciscoes, suckers , burbot, gar, and sculpins- are important because of their ecological significance; intrinsic value; and social, cultural, and economic benefits.	*Most of the seldom seen but ecologically important indigenous species of fish occupy the nearshore areas throughout the Lake Huron basin. Many of them are associated with specific shoreline types and are thus vulnerable to shoreline alteration or destruction.*
Protect and enhance fish habitat and rehabilitate degraded habitats. *Achieve no net loss of the productive capacity of habitat supporting Lake Huron fish communities and restore damaged habitats.* *Support the reduction or elimination of contaminants.*	*The alteration of nearshore areas due to human activities has been widespread and has had a detrimental impact on fish production and diversity. The Lake Huron basin has a variety of shoreline features that support diverse fish communities. These shorelines are dynamic and influence currents, substrate composition, and deposition zones. Fluctuating lake levels are a natural feature in the basin and need to be recognized as an important mechanism for rejuvenating and structuring nearshore features such as beaches, wetlands, and riparian vegetation.*

Background:

The Lake Huron basin has by far the largest extent of shoreline habitat amongst the Great Lakes. In Canadian waters, over 2,044 km of mainland shoreline exists with an additional 2,768 km of island shoreline (International Joint Commission 1989, 1993). In U.S. waters, 933 km of mainland and 414 km of island shoreline are found. The St. Marys River adds another 150 km of mainland and 240 km of island shoreline along an international boundary. The nearshore waters, those waters with depths less than 30 m, adjacent to these shorelines represent 25.7% of the entire Lake Huron surface area and 4.2% of its volume (Edsal and Charlton 1997).

These areas, where water and land meet, provide links between highly productive nearshore areas and offshore habitats and are considered “centers of organization” for fish communities (Steedman and Regier 1987). A diversity of habitat functions are supported here ranging from providing access to coastal and estuarine reproductive areas, linking reefs and shoals to larval productivity centers, and facilitating the interaction between lake processes and shoreline morphology (Halyk et al. 1999). The structural diversity of nearshore areas provides an abundance of different “Eco Zones”, areas possessing a unique range of substrate, energy and water mass characteristics that support a variety of fish species and communities (Mackey 2003).

Virtually all species of Great Lakes fish use nearshore waters for one or more critical life-stages or functions (Lane et al 1996a,b), thus the nearshore area hosts Lake Huron’s highest diversity of fish species. In 1993, for example, 47 species of fish were sampled in night-time seine hauls between Hammond Bay and Saginaw Bay (MDNR Alpena Fisheries Research Station, unpublished data). Some species like black bass are permanent residents in nearshore waters, typically in sheltered, rocky embayments. For others, such as rainbow trout and Chinook salmon, nearshore areas act as migratory pathways for anadromous fish. Still other species such as lake whitefish use nearshore areas as temporary larval feeding grounds before moving to offshore waters (Reckahn 1970; Loftus 1977, 1979). Density of prey fish is much higher in nearshore waters than in deeper offshore waters and according to some estimates contain up to 62% of the total biomass of prey fish in Lake Huron (Argyle 1982).

Protecting, maintaining and rehabilitating shoreline form and function will ensure that critical spawning, nursery and feeding habitats will be available for a variety of fish species and communities. Structurally diverse and unique shoreline features will assist in the maintenance and preservation of aquatic biodiversity in the Lake Huron basin.

Description of issues:

Although the nearshore zone in the Lake Huron basin is vast, it is vulnerable to alteration due to human use. Across the Great Lakes, shorelines have been altered or destroyed through activities such as dredging, diking, infilling, shoreline armouring, breakwater construction, as well as thermal and nutrient discharges (Edsall and Charlton 1997). On Lake Huron, most of these activities are concentrated in urbanized areas in the southern part of the basin, however, over the last 20 years there has been a trend towards increasing pressure for seasonal land uses especially cottages that often result in shoreline alterations (Bredin 2002).

In some shoreline segments in the basin up to 10% have been hardened or rip-rapped and have likely altered previous shoreline function and productivity (Reid et al. 2000). In Severn Sound of Georgian Bay, approximately 15% of the 325 km of shoreline has been altered (Edsall and Charlton 1997). More recently, legislation has been passed in Michigan allowing private landowners to remove vegetation from beech areas and till exposed bottom lands.

On the St. Marys River, the shoreline and river channel have both been impacted by large commercial vessel passage due to channel dredging and spoils disposal, altered water level and flow conditions and the erosion effects of large wakes (Poe and Hiltunen 1980). This large vessel traffic has also had a negative effect on lake herring egg survival due to excessive wakes and turbulence (Savino et al. 1994). Channelization for navigation may have eliminated many spawning sites for lake herring, which appear to select lacustrine habitats of the river for egg deposition. Navigation channels appear to increase current velocities beyond those suitable for spawning (Fielder 1998).

The outcome of these shoreline alterations usually is the loss of fish production or change in fish community structure. Straightening shorelines results in a loss of habitat diversity and an increase in the deposition of fine sediments and organic material in offshore areas that in turn smother spawning areas (Edsall and Charlton 1997). Beach erosion control and navigation structures interrupt shoreline sediment transport, starve down-current beaches and increase shoreline erosion offsite (Edsall and Charlton 1997). The degradation or alteration of nearshore habitats usually results in the reduction of desirable species (piscavores) and an increase in the spatial variability in species richness and biomass (Randall et al. 1993).

Although most nearshore modifications have local or cumulatively regional effects, some alterations such as large scale dredging can have whole basin impacts. At the outflow of Lake Huron on the St.Clair River, dredging for commercial gravel extraction in the 1920s and navigational improvements in 1933 and 1962 resulted in a permanent lowering of lake levels of 0.27 m (Derecki 1985). Smaller scale dredging can also have more local negative impacts by re-suspending contaminated sediments, altering currents and physically modifying habitats (Edsell and Charlton 1997).

Climate change would likely exacerbate effects of anthropomorphic alterations of the nearshore zone. Some climate models predict a decline in lake levels in the 21st century (Kunkel et al. 2002). Even though water level fluctuations on Lake Huron are a natural phenomenon following seasonal, annual and longer term fluctuations of up to 1.5 m (Thompson and Baedke 1997; Baedke and Thompson 2000), areas that are temporarily exposed during low water cycles are vulnerable to alteration. If unaltered, wetlands can experience a period of renewal during declining phases of the water cycle, expanding their ranges to deeper contours of the lake bed. These types of areas have been shown to be important for yellow perch (Henderson 1985) and northern pike reproduction, especially during the rising portion of the water cycle (Bodaly and Lesack 1984).

Nearshore ecosystems of Lake Huron are not well studied and therefore the responses of fish and associated biological communities to natural- and human-induced environmental changes in nearshore areas are generally not well understood (Goforth and Carman 2003). Numerous knowledge gaps exist with respect to fish species and critical habitats and until these are addressed, there should be urgency in protecting intact nearshore habitats and restoring degraded ones.

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Summary of current and historic data:

The detailed physical characterization of nearshore aquatic habitats and associated fish community structure in the Lake Huron basin is incomplete and in most cases restricted to specific areas and time-frames. The most detailed coverage is found in AOCs and to a lesser extent in a limited number of areas scattered throughout the basin.

A detailed ecological profile of the St. Marys River provides a comprehensive review of fish community structure as well as physical features of this Great Lakes connecting channel (Duffy and Batterson 1987). The profile provided a perspective on the geological setting of the St. Marys River and provided an historical perspective of resource exploitation and habitat alteration. The river supported a percid type community (Ryder and Kerr 1978) with walleye and yellow perch widely distributed and northern pike and white suckers also present. The more open waters supported populations of lake herring and rainbow smelt and a variety of salmonids utilized the rapids area. In spite of the high diversity of species occupying the river, fish production was compromised by commercial navigation, barriers to fish movement, wetland loss and exotic species proliferation, primarily sea lamprey.

In Saginaw Bay, the Michigan Department of Natural Resources (MDNR) has conducted intensive trawl and gillnet surveys 1970 – 2003 (Fielder et al 2000; MDNR, unpublished data). In the trawl surveys, the most abundant species were yellow perch, rainbow smelt, spottail shiner, trout-perch and alewives. Historically important species such as lake sturgeon and lake herring were not captured during these surveys. Juvenile whitefish and walleye were commonly caught in trawls indicating a recovery from long-term declines. In general, the Saginaw Bay area was dominated by prey fish with predators being scarce (Haas 1995; Fielder 2002). The slow recovery of walleye resulting from a combination of habitat deterioration and effects of exotic species has contributed to this imbalanced resident fish community (Fielder et al. 2000; Fielder 2002; Fielder and Baker In Press).

Brown et al. (1995) studied fish habitat and fish community structure for St. Martin's Bay in northern Lake Huron. This study examined prey fish assemblages in littoral and nearshore areas using a variety of sampling gear including beach seins, bottom trawls and mid-water trawls, over a variety of depths and bottom substrates ranging from sandy to vegetated areas. Results varied according to sampling methodology, however, some observations were revealing. The abundance of exotic prey species varied seasonally, with smelt abundant in the spring and alewives in September. Exotic species were more prevalent in rock substrate as opposed to native prey species that were more abundant over sand/vegetated substrates. Exotic species were a significant component of the prey fish assemblage in the littoral and nearshore zones of St. Martin Bay and yellow perch and lake herring that were historically important in these habitats had declined to very low levels.

In a limited number of areas, efforts have been made to develop a habitat classification system for littoral habitats in the Great Lakes including the Lake Huron basin. An extensive study which collected fish assemblage and habitat data from several Great Lakes Areas of Concern, including Severn Sound, formed the basis for developing and evaluating an Index of Biotic Integrity (IBI) for littoral fish (Minns et al. 1994). An extension of this work has incorporated a Geographic Information System (GIS) which integrates habitat data (substrate, depth, vegetation) with biological information (Minns et al. 1999). By examining the habitat requirements of Great Lakes fish, fish utilization of different littoral habitats can be predicted. Detailed maps of nearshore habitat were produced over several years for the shoreline of Severn Sound. Habitat suitability classification and mapping were performed using colour coding to indicate importance of habitat to fish. The results of these efforts are meant to guide local and regional planning initiatives by applying restrictions to areas identified as having high biodiversity investment values.

Additional information on nearshore habitats such as shoreline features and fish community composition is available. The “Environmental Sensitivity Atlas for Lake Huron’s Canadian Shoreline” was designed for use in responding to spills of oil and other hazardous materials (Environment Canada 1994). The survey collected videotaped shoreline footage from a helicopter, classified shoreline, acquired biological and human resource data, and stored this information on a GIS-like electronic desktop environmental sensitivity mapping system. The shoreline project classified shoreline units into 19 different shoreline habitat types, ranging from wetlands to developed shorelines. Important features such as known areas of spawning and migration activity for fish species having commercial or recreational value were incorporated into the GIS maps. An environmental sensitivity index ranking was also developed to prioritize responses to oil or other toxic spills. The resulting data base provides a coarse-level perspective of nearshore habitat attributes throughout the Canadian shoreline of Lake Huron.

The State of the Lake Ecosystem Conferences (SOLEC) sponsored by the U.S. Environmental Protection Agency and Environment Canada provided further documentation and summarization of nearshore aquatic habitat resources in the Lake Huron basin. For the nearshore, three types of summarized information were compiled based on the Biodiversity Investment Areas (BIA) concept introduced at SOLEC 1996 (Reid and Holland 1997). The BIA approach recognizes that some sections of the Great Lakes have exceptionally high ecological values that warrant special protection. The three types of BIAs included aquatic ecosystems, coastal wetland ecosystems and terrestrial ecosystems. This effort was further extended to integrate all three types of BIAs into one BIA designation that would provide an indication of nearshore areas of regional significance (Reid et al 2000). The results of the composite ranking identified the following as priority habitat areas in Lake Huron; Mackinac-Manitoulin archipelago, the St. Marys River and eastern Georgian Bay (Reid et al. 2000).

These efforts have provided some indication of the distribution of important nearshore areas in the Lake Huron basin. In many cases however, fish community data were incomplete or dated. Nearshore habitat classification and mapping need to be completed. In some cases, agency-collected fish information from nearshore surveys have yet to be integrated into habitat features data. An example would be the Nearshore Community Index Netting conducted by the Ontario Ministry of Natural Resources throughout eastern Georgian Bay and the North Channel.

Information on the rate of nearshore habitat alteration or loss is available from the Canadian Department of Fisheries and Oceans (DFO) which is responsible for enforcing the habitat protection provisions found in the Canadian Fisheries Act. The Act prohibits any work or undertaking that is likely to result in the harmful alteration, disruption, or destruction (HADD) of fish habitat without the implementation of compensatory measures. These provisions are part of DFO policy for the management of fish habitat that has an overall objective to “increase the natural productive capacity of habitats for the nation’s fisheries resources, to benefit present and future generations of Canadians” (DFO 1986). Information on the type of projects assessed by DFO under the “no net loss” policy for fish habitat is available for Lake Huron. There is a need to

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determine the cumulative impact of proposals and to develop long-term habitat management plans to effectively deal with this issue.

Further support for the collection of nearshore aquatic ecosystem information may be possible through recent planning initiatives such as Ontario's Living Legacy program, sponsored by the Ontario Ministry of Natural Resources. This program has identified massive tracts of nearshore lands along eastern Georgian Bay, the North Channel and northern Lake Superior as special management areas. Although in its early strategic planning stage, an effort is underway for a more detailed aquatic and terrestrial resource data gathering exercise.

The State of Michigan holds the bottom lands of Lake Huron to the normal high water mark within its jurisdiction as a trust responsibility to the citizens of the state. As such, these lands are considered public domain and permits are required for their alteration. There have been recent legislative initiatives aimed at weakening the State's responsibility in favour of private property rights, however. The Michigan Natural Features Inventory, a joint venture between Michigan State University and MDNR, has conducted extensive inventory, classification and mapping of nearshore habitats. The Nature Conservancy has joined in classification, mapping, and acquisition of more sensitive nearshore habitats, particularly in northern Lake Huron.

Priority areas and issues:

The large extent and diversity of shoreline habitat throughout the Lake Huron basin adds to the overall fish community structure and Lake Huron's remarkable fish species diversity. Even small losses or alteration of nearshore habitat result in incremental loss or changes in fish production; larger-scale alterations such as navigational dredging or unfriendly shoreline protection policies can have longer, more profound impacts on fish production and fish community structure.

The following is a list of Priority Management Areas (PMAs) and some of their attributes:

Saginaw Bay

- Shoreline alteration extensive and ongoing
- Many coastal wetlands remain disconnected from the bay
- Nearshore areas impacted by excessive sedimentation and nutrient enrichment
- A considerable effort has been made to classify and map wetlands of the bay
- Enhanced measures to protect natural shorelines are needed

Central and south-east shore of main basin

- A high energy, dynamic shoreline
- Area of extensive shoreline hardening
- Ongoing construction of dikes, piers, and other erosion control structures
- Dredging activities at lake outflow have caused permanent water level declines in the whole basin
- Information needed on fish community association with critical nearshore habitats

St. Marys River

- Extensive shoreline hardening and alteration
- Navigational dredging and spoils disposal impacting sediment transport
- Shipping and ice breaking promoting shoreline erosion
- Information needed on fish community association with critical nearshore habitats

Southern Georgian Bay

- Extensive shoreline alteration from marina expansion and residential property development
- Loss of historical wetlands
- Shoreline hardening of rivermouths
- Nearshore currents altered by piers and other erosion control structures
- Information needed on fish community association with critical nearshore habitats

Thunder Bay

- Navigation channels have altered nearshore habitat features
- Beach construction has changed shoreline contours and water current dynamics
- Shore line disposal of cement kiln dust has altered large reaches of shoreline
- Information needed on fish community association with critical nearshore habitats

Les Cheneaux Islands

- Navigation channels have altered some nearshore habitat features
- Commercial development is altering shoreline areas
- Sensitive shoreline features are vulnerable to alteration
- Concentration of coastal wetlands
- Information needed on fish community association with critical nearshore habitats

Eastern Georgian Bay/North Channel

- Sensitive shoreline features
- Extensive shoreline alteration from marina expansion and residential property development
- Loss of historical wetlands
- Boat wakes are causing accelerated erosion of nearshore areas
- Information needed on fish community association with critical nearshore habitats

Information and Research needs:

The following is a list of information and research needs as they relate to this Environmental Objective:

- Establish a quantitative relationship between cumulative shoreline alteration and changes to nearshore function
- Develop habitat protection plans for areas containing high quality fish habitat
- Initiate a comprehensive survey of nearshore areas in the basin to identify critical habitat areas
- Identify nearshore areas providing critical habitat for rare, threatened or endangered fish species
- Identify locations for habitat rehabilitation and prioritize them
- Quantify the extent of shoreline armouring and develop a strategy to minimize impacts
- Update fish spawning and nursery habitat data
- Develop additional measures of aquatic productivity such as comparative studies of nearshore benthic invertebrates
- Pursue a habitat supply analysis for individual species or groups of fish
- Determine how commercial shipping and high density recreational boating can impact shoreline dynamics and recovery of sensitive littoral zone habitats
- Develop inventory of species occupying beach zones

Many of these PMAs have also been identified as important Biodiversity Investment Areas (BIA). The concept of BIA, areas of the Great Lakes that have exceptionally high ecological values and that warrant special status and protection, was put forward at the State of the Lake Ecosystem Conference, 1996.

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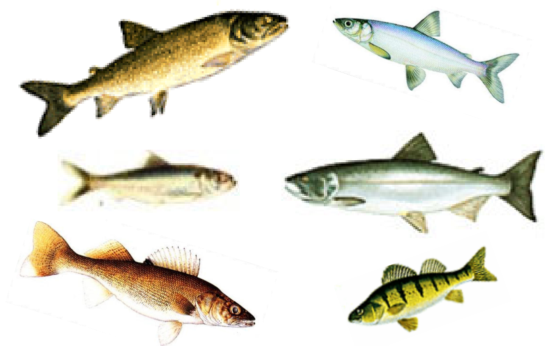
3. Food Web Structure and Exotics

Protect and where possible enhance or restore fish community structure and function by promoting native species abundance and diversity and avoiding further exotic species introductions. In particular, protect and restore keystone predators to control exotic species and cultivate a food web favorable to reproduction of native species.



Relevance to Fish Community Objectives:

Fish Community Objectives	Importance of Environmental Objective
Establish a diverse salmonine community that can sustain and annual harvest of 2.2 million kg with lake trout the dominant species and anadromous (stream-spawning) species also having a prominent place.	*The primary prey base for salmonids in the Lake Huron basin is the exotic alewife and to a lesser extent rainbow smelt. However, these exotic prey species are predators on YOY salmonids and negatively impact early development success of salmonids due to Early Mortality Syndrome. Other exotics such as zebra mussels colonize spawning reefs used by lake trout and round gobies are effective egg predators in these locations.*
Maintain the present diversity of coregonines. *Restore lake herring to a significant level and protect, where possible, rare deepwater ciscoes.*	*Coregonids, especially lake herring, have been negatively impacted by exotic prey species such as alewives and rainbow smelt due to their predation on YOY. These exotic species also compete directly with coregonids for food, particularly during their early life-history stages. Zebra mussels are diminishing food resources for both juvenile and adult coregonids and round gobies may become a significant egg predator on whitefish spawning reefs.*
Re-establish and/or maintain walleye as the dominant cool-water predator over its traditional range with populations capable of sustaining a harvest of 0.7 million kg. *Maintain yellow perch as the dominant nearshore omnivore while sustaining a harvestable annual surplus of 0.5 million kg.*	*Walleye fry are consumed by exotic alewives and rainbow smelt. Alewives in Saginaw Bay and else where compete with juvenile walleye and yellow perch for food resources.*

Recognize and protect the array of other indigenous fish species because they contribute to the richness of the fish community. These fish- cyprinids, rare ciscoes, suckers, burbot, gar, and sculpins- are important because of their ecological significance; intrinsic value; and social, cultural, and economic benefits.	*Native sculpins and other species may be displaced by exotic species such as round and tube nosed gobies and Eurasian ruffe.*
Maintain northern pike as a prominent predator throughout its natural range *Maintain muskellunge in numbers and at sizes that will safeguard and enhance its special status and appeal*	*Exotic species such as carp have a negative impact on esocids through their habit of uprooting vegetation and increasing turbidity in wetland spawning areas.*
Protect and enhance fish habitat and rehabilitate degraded habitats. *Achieve no net loss of the productive capacity of habitat supporting Lake Huron fish communities and restore damaged habitats.* *Support the reduction or elimination of contaminants.*	*Exotic species have altered the biotic, physical and chemical attributes of spawning, nursery, and feeding habitats throughout the Lake Huron basin. Predator-prey dynamics have been profoundly altered and the efficient transfer of energy from one trophic level to another has been compromised. The decline in Diporeia has degraded nutritional value of benthos available to native species and eliminated their role in recycling of detritus to the water column.*

Background:

The native fish communities of Lake Huron reflect the diversity of aquatic habitats and recent glacial history of the basin (Table 2). Historically, the offshore fish communities were characteristic of a large, deep oligotrophic lake with lake trout and burbot being the dominant predator and a variety of cisco species being the dominant prey species (Berst and Spangler 1973). In the nearshore waters, a relatively greater diversity of predators (walleye, northern pike, muskellunge, bass) were present as well as benthivores (sturgeon, suckers, channel catfish) and prey fish (herring, yellow perch, cyprinids) (Christie 1974; Ebener et al.1995). Over 92 species of fish in 24 families were present in the Lake Huron basin excluding tributaries (DesJardine et al. 1995) (Table 2).

Although these historic fish communities were rather simple they were highly evolved structurally despite the relatively short period of time since glaciation (Eshenroder and Burnham-Curtis 1999). The cisco species complex was diverse (Smith and Todd 1984) and occupied most of the offshore waters providing a diversity of prey, both in terms of depth distribution and body size, for the diversity of lake trout forms that also occupied these areas (Smith 1972; Eshenroder et al. 1995). Lake herring, preferring the shallowest water among the native coregonids (Scott and Crossman 1973), was a prominent prey fish throughout the basin. In the nearshore and connecting channels, a complex fish community evolved with warm and coolwater species having prominent roles.

The loss during the 1930s and 1940s of Lake Huron's keystone predators, lake trout and walleyes, permitted the unfettered expansion of first rainbow smelt, then alewives. Control of these exotic prey species has been gained through prodigious investments by resource management agencies (Whelan and Johnson 2004). Alewives and smelt remain the principal prey for larger predators, however, and as the abundance and average size of these prey has declined, growth rates of lake trout (Johnson et al. 2004) and chinook salmon (Woldt et al. 2003) have declined and age at maturity of lake trout has increased (MDNR unpublished data). The recent collapse of Diporeia (Nelapa and Tuchman 2000) has caused major shifts in diets of coregonids and may be contributing to increasing age of maturity and declining growth rates in lake whitefish. The zebra/quagga mussel based benthic food web may prove much less effective in transferring energy to native species than the native food web which was dominated by crustaceans.

Protecting, enhancing and restoring fish community structure and function in the Lake Huron basin will ensure the efficient utilization and transfer of energy from the various trophic levels and promote the sustainability of desired species and communities. Discouraging the proliferation of exotic species will also enhance efforts at rehabilitating historically important species such as lake trout, lake herring, walleye and lake sturgeon as well as promote the pursuit of biodiversity within the basin.

Description of issues:

Fish communities throughout the Lake Huron basin have undergone substantive change over the last century. A variety of factors have been implicated in the loss or extinction of species in the basin such as over-exploitation for sturgeon, deepwater ciscoes, whitefish, lake trout and lake herring (Van Oosten et al. 1946; Berst and Spangler 1973; Brown et al. 1987; Eshenroder 1992), habitat loss combined with overfishing leading to the loss of herring and walleye in Saginaw Bay (Kellar et al. 1987) and loss of access to sturgeon spawning grounds due to dam construction (Ono et al. 1983). The focus of this discussion however will be on the impact that exotic species have had on the biotic environment of fish communities in the basin.

The first wave of exotics arriving in the 1920s and 1930s involved a trio of species, sea lamprey (*Petromyzon marinus*), alewife (*Alosa pseudoharengus*), and rainbow smelt (*Osmerus mordax*) (Eshenroder and Burnham-Curtis 1999), all ocean-dwelling fish originating from the east coast of North America. The sea lamprey likely had the most profound impact on fish community structure and by the 1960s lamprey predation was considered to be the leading cause of the collapse of most fish populations in Lake Huron (Berst and Spangler 1973; Coble et al. 1990). Lake trout are particularly vulnerable to sea lamprey and as the keystone predator in the basin its near extirpation set in motion the increase in abundance of both alewife and smelt and the extinction of several deepwater cisco species (Eshenroder and Burnham-Curtis 1999).

Alewives and smelt continue to play a major role in structuring the Lake Huron fish community. Both species have a propensity for consuming young-of–the-year (YOY) of native species including lake trout (Johnson and Van Amberg 1995; Krueger 1995), lake whitefish, lake herring, walleye (Krishka et al. 1996), and yellow perch (Smith 1970). They also compete directly for food resources with lake herring (Anderson and Smith 1971; Selgeby et al. 1978), bloater (Stedman and Argyle 1985), lake whitefish (Loftus and Hulsman 1986), and yellow perch (Keller et al 1987;

Haas and Schaeffer 1992). Both species continue to be the dominant prey base for fish predators such as lake trout and Chinook salmon (Dobeisz and Bence 2000) as well as walleye (Schneider and Leach 1977). This dependence on alewives in particular has caused additional negative consequences through reduced egg survival and developmental problems in lake trout resulting from Early Mortality Syndrome (EMS) (Fitzimmons et al. 1999). Lake trout growth rates have declined while age at first maturity has increased, leading to lower reproductive potential in terms of annual lake trout egg deposition. A leading cause of this decline is the small body size of rainbow smelt and alewives, decline in biomass of older alewives and smelt, and lack of an alternative larger-bodied prey such as lake herring.

The specter of more fish community disruption in the Lake Huron basin arose as the result of a new wave of exotic species including the spiny-tailed water fleas (Bythotrephes cederstroemi) (Bur et al. 1986); zebra mussels (*Dreissena polymorpha*) (Griffiths et al. 1991), Eurasian ruffe (*Gymnocephalus cernuus*) (Busiahn and McClain 1995), and round gobies (*Neogobius melanostomus*) (Jude et al 1992), all of which arrived since 1980 as a result of ballast water exchange (Mills et al. 1993; Nalepa and Schlosser 1993). The full impact of these introductions is still not completely understood but zebra mussels have already had a pronounced impact on nutrient cycling and benthic community composition throughout the basin. Zebra mussels are the likely cause in the decline of macroinvertebrates, particularly Diporeia (Nalepa et al. 1998; Lozano et al. 2001), a bottom dwelling amphipod that serves as an important food source for a wide range of fish species.

The benefits of restoring native food web structure are many. Native planktiverous fish such as the deepwater cisco differ from exotic species such as alewife or smelt by virtue of their enhanced buoyancy regulation and ability to assimilate nutrients at widely varying temperatures, thus making them more adapted to the deepest waters of the Great Lakes (Eshenroder and Burnham-Curtis 1999). Further, the larger range of body size of coregonids renders them suitable as prey for lake trout of all sizes. For offshore waters of the lake, two successional states are believed to be sustainable, one where alewives dominate and pisciverous predators are not abundant, as was the case prior to approximately 1970, or one sustained by effective controls of sea lampreys and overfishing, and dominated by predators such as lake trout and walleyes, which suppress alewives and smelt to levels that favor recovery of native prey species (Eshenroder and Burnham-Curtis 1999). For Lake Huron, the factors preventing this latter sustainable state may be the continued high abundance of lampreys in the basin, hatchery/domestication attributes of stocked lake trout that lower their reproduction efficiency, genetic diversity of lake trout available for stocking, and overfishing of lake trout (Eshenroder et al. 1995).

The current fish community structure of Lake Huron is heavily influenced by exotic species at the expense of native species, many of which have declined to very low levels or have been extirpated from the basin. The dominance of an exotic prey base has also necessitated the need for an extensive predator stocking program, estimated to cost Lake Huron management agencies an average of $6,842,000 annually, that includes both native lake trout and introduced Pacific salmon (Whelan and Johnson 2004). Declines have been measured in both biomass of older alewives and smelt and in their average size and age (USGS unpublished data). These declines appear to be driven in part by a combination of relatively severe winters and increasing predation rates, which in turn may be due to effects of chinook reproduction (Lake Huron Technical Committee unpublished data) and more effective sea lamprey control (Schleen et al. 2003). Management actions that favor the continued suppression of exotic prey species and rehabilitation of native species should be considered a high priority.

Opportunities exist to foster the recovery of historically important species such as lake herring, lake sturgeon, walleyes and lake trout. Reproducing populations of each of these species exist in the basin but more needs to be done to ensure their ranges are expanded to former areas of abundance. A diverse, functioning fish community with good representation from native species should make these communities more productive, stable, resilient and sustainable (DesJardine et al. 1995). These properties are particularly important in light of the potential for additional exotic species introductions such as Asian and grass carp. Additional emerging issues associated with exotic species are often times unanticipated such as the apparent consequences of biomagnification of contaminants resulting from goby predation on zebra mussels causing botulism outbreaks (Domske 2003).

There is growing evidence that recovery of some native species is hindered by the predatory effects of exotic planktivores on the juvenile life stages of native species. A cultivation / depensatory hypothesis has been formulated by Walters and Kitchell (2001) proposing that disrupted fish community assemblages can result in a predatory juvenile bottleneck where over abundant prey prevent sufficient recruitment levels of certain predators. This has been a mechanism offered as one of the inhibitors to walleye recovery in Saginaw Bay (Fielder and Baker In Press).

Summary of current and historic data:

The status of most fish communities throughout the Lake Huron basin is monitored, however, some critical gaps exist. A significant amount of fish community information is collected from an active commercial fishery in both U.S. and Canadian waters. These fisheries primarily harvest lake whitefish and deepwater chub and to a lesser extent walleye and yellow perch in Canadian waters. Lake trout comprise a significant portion of fish harvested from these fisheries primarily as incidental catch. Annual monitoring of commercial catch is conducted by the Michigan Department of Natural Resources (MDNR), Inter-tribal Fisheries and Assessment Program of the Chippewa/Ottawa Resource Authority (CORA), the Ontario Ministry of Natural Resources (OMNR), and the Chipewas of Nawash and Saugeen.

In addition to monitoring commercial catch, the MDNR, U.S. Fish and Wildlife Service (USFWS), CORA and OMNR conduct annual assessments of the offshore fish community at a variety of locations situated throughout the basin. Nearshore fish community assessment is not as extensive and is primarily focused on major recreational fisheries such as Saginaw Bay, Les Cheneaux Islands, the St. Marys River and eastern Georgian Bay.

Annual prey fish monitoring is primarily conducted by the United States Geological Survey (USGS) at a number of locations situated predominantly in U.S. waters of the main basin, with a few locations sampled intermittently in Canadian waters of the main basin and even less frequently in Georgian Bay and the North Channel. Nearshore prey fish and exotic species assessment is even less comprehensive with sampling sites monitored at irregular intervals and at a limited number of sites primarily in U.S. waters. Nearshore exotic species surveillance and population monitoring is conducted annually at Saginaw Bay and at several additional U.S. ports by the U.S. Fish and Wildlife Service.

An elaborate program of monitoring and control of sea lampreys is coordinate and funded through the Great Lakes Fishery Commission and conducted jointly by the USFWS and the Canadian Department of Fisheries and Oceans (DFO). Lamprey control is an integrated program that utilizes chemical control, tributary barriers, lamprey traps and sterile-male release to control lamprey abundance throughout the Lake Huron basin (Morse and Young 2003). The lamprey control program on Lake Huron has been in place since 1960 and since that time 92 tributaries have received some form of lamprey control treatment (Morse and Young 2003). Since 1997, an integrated sea lamprey control program was initiated on the St. Marys River (Schleen et al. 2003), the largest source of lampreys in the Great Lakes basin (Morse et al. 2003). Early results suggest the St. Marys River control program is achieving a significant reduction in sea lamprey. The ultimate target is to achieve the fish community objective of a 90% reduction from sea lamprey numbers that prevailed in the early 1990s.

Priority areas and issues:

The fish community in the Lake Huron basin is altered substantially from its historical structure. The current fish community is comprised of a mix of both native and non-native predators and dominated by a non-native prey base. Opportunities for enhancing native species production need to be identified and utilized in order to establish a more stable fish community assemblage.

The following is a list of Priority Management Areas (PMAs) and some of their attributes:

Main Basin

- One of the priority areas for lake trout rehabilitation
- Currently supports a substantial native and non-native predator population
- Exotic species are the primary prey base and are showing signs of decline
- Diporeia populations are declining
- Lake whitefish condition is declining
- Lake herring distribution confined to north shore
- Expanding lake herring distribution to the west shore (Thunder Bay) should be pursued

Saginaw Bay

- Currently this area continues to be dominated by an excessive abundance of non-native prey species
- Promoting the continued recovery of walleye as a primary predator is paramount for a larger balanced fish community in this portion of Lake Huron.
- Re-establishing lake herring as a native prey fish should be pursued
- Improving the production of yellow perch should also be a priority
- Enhancing the abundance and distribution of other coolwater predators such as northern pike and restoring muskellunge populations should be made a priority

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St. Marys River

- Currently supports a complex community of cold, cool and warmwater species
- Coldwater predators are primarily exotic salmonids and are mostly transitory in the river
- Maintaining native coolwater predators should be a priority
- Rehabilitating walleye stocks should be a priority throughout the river
- Maintaining the native lake herring stocks is also crucial for native prey base support and as a possible seed source for other portions of Lake Huron
- Continued suppression of sea lamprey needs to be a high priority

Les Cheneaux Islands

- An important coolwater mix of species in northern Lake Huron
- One of the few remaining refuges for lake herring
- Needs continued monitoring to understand recent declines in yellow perch

Severn Sound

- Historically supported diverse cold, cool and warmwater fish community
- Improvements to local water quality may promote recovery of coldwater community
- Lake herring have increased in abundance
- Prey base is a mixture of native and non-native species
- Several new exotic species may further disrupt balance of native and non-native species

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Information and research needs:

The following is a list of information and research needs as they relate to this Environmental Objective:

- Develop and implement a strategy to address the problem of ballast water introductions
- Enhance and expand baseline data on fish communities to detect changes introduced by invasive species
- Expand surveillance sampling to identify new colonizations particularly in Ontario waters
- Investigate and monitor other potential sources of exotic species introductions (i.e. live fish markets)
- Enhance information/education programs to further public understanding of the threat of exotic species
- Continue to apply an integrated pest management approach to control of sea lampreys in the St. Marys River and introduce more effective control measures such as pheromone attractants, as they become feasible
- Estimate natural recruitment of chinook salmon in Lake Huron
- Conduct research into sites of origin of wild chinook recruitment in Lake Huron by using trace element analysis of otoliths and other methods

- Conduct research into sites of origin of wild walleyes by using trace element analysis of otoliths and other methods
- Determine how diets and bioenergetics of whitefish are affected by changes to the Lake Huron food web
- Conduct pilot research projects into methods for culture and introduction of lake herring
- Develop management policies to guide rehabilitation of lake herring
- Maintain high predation rates on alewives and smelt to reduce their effects on walleye and lake trout reproduction
- Seek to establish an index survey for near shore fishes in the main basin
- Agencies should investigate food web factors that may influence prey base thiaminase activity
- Assess the sub-lethal consequences of low thiamine on fry survival, recruitment, and long-term viability of lake trout and other salmonines
- Initiate investigations to better understand and quantify the effects of egg and fry predation by exotic species on native species and how this predation may be impeding recovery efforts

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Table 2. Common and scientific names of fishes (AFS 1991) referenced in the state of the lake report. Asterisk indicates the species is extinct in Lake Huron. (Taken from Ebener 2003).

Common name	Scientific name
Indigenous species	
Cold water	
Artic grayling*	*Thymallus arcticus*
Bloater	*Coregonus hoyi*
Blackfin cisco*	*Coregonus nigripinnis*
Brook trout	*Salvelinus fontinalis*
Deepwater cisco*	*Coregonus johannae*
Deepwater sculpin	*Myoxocephalus thompsoni*
Kiyi*	*Coregonus kiyi*
Lake herring	*Coregonus artedi*
Lake trout	*Salvelinus namaycush*
Lake whitefish	*Coregonus clupeaformis*
Longjaw cisco*	*Coregonus alpenae*
Longnose sucker	*Catostomus catostomus*
Round whitefish	*Prosopium cylindraceum*
Shortjaw cisco*	*Coregonus zenithicus*
Shortnose cisco	*Coregonus reighardi*
Cool water	
Burbot	*Lota lota*
Grass pickerel	*Esox americanus vermiculatus*
Johnny darter	*Etheostoma nigrum*
Lake sturgeon	*Acipenser fulvescens*
Logperch	*Percina caprodes*
Longnose dace	*Rhinichthys cataractae*
Muskellunge	*Esox masquinongy*
Northern pike	*Esox lucius*
Nine-spine stickleback	*Pungitius pungitius*
Sand shiner	*Notropis stramineus*
Slimy sculpin	*Cottus cognatus*
Spottail shiner	*Notropis hudsonius*
Trout-perch	*Percopis omiscomaycus*
Walleye	*Stizostedion vitreum*
Yellow perch	*Perca flavescens*
Warm water	
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*

Table 2 cont'd

Common name	Scientific name
<u>Warm water</u>	
Channel catfish	*Ictalurus punctatus*
Freshwater drum	*Aplodinotus grunniens*
Green sunfish	*Lepomis cyanellus*
Largemouth bass	*Micropterus salmoides*
Longear sunfish	*Lepomis megalotis*
Pumpkinseed	*Lepomis gibbosus*
Rock bass	*Ambloplites rupestris*
Smallmouth bass	*Micropterus dolomieu*
White crappie	*Pomoxis annularis*
White sucker	*Catostomus commersoni*
Non-indigenous species	
<u>Cold water</u>	
Atlantic salmon	*Salmo salar*
Brown trout	*Salmo trutta*
Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*Oncorhynchus kisutch*
Kokanee salmon	*Oncorhynchus nerka*
Pink salmon	*Oncorhynchus gorbuscha*
Rainbow smelt	*Osmerus mordax*
Rainbow/steelhead trout	*Oncorhynchus mykiss*
Sea lamprey	*Petromyzon marinus*
<u>Cool water</u>	
Alewife	*Alosa pseudoharengus*
Three-spine stickleback	*Gasterosteus aculeatus*
Round goby	*Neogobius melanostomus*
Ruffe	*Gymnocephalus cernuus*
<u>Warm water</u>	
Gizzard shad	*Dorosoma cepedianum*
Common carp	*Cyprinus carpio*

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4. Water Quality

Protect and restore water quality throughout the Lake Huron basin, especially in the Areas of Concern, and reduce or remove contaminant burdens from the fish community in order to avoid reductions in fish production and native species biodiversity, and to maintain fishable, swimable, aesthetically unaltered waters for the enjoyment of future generations.

Relevance to Fish Community Objectives:

Fish Community Objectives	Importance of Environmental Objective
Establish a diverse salmonine community that can sustain an annual harvest of 2.2 million kg with lake trout the dominant species and anadromous (stream-spawning) species also having a prominent place.	*Lake trout are subject to consumption advisories due to bioaccumulation of contaminants throughout the basin. Other salmonid species also have varying levels of consumption advisories in several locations throughout the Lake Huron basin.*
Maintain the present diversity of coregonines. *Manage lake whitefish and ciscoes at levels capable of sustaining annual harvests of 3.8 million kg.* *Restore lake herring to a significant level and protect, where possible, rare deepwater ciscoes.*	*Lake whitefish are subject to varying levels of consumption advisories due to contaminant levels in a number of locations throughout the basin.*
Re-establish and/or maintain walleyes as the dominant cool-water predator over its traditional range with populations capable of sustaining a harvest of 0.7 million kg. *Maintain yellow perch as the dominant nearshore omnivore while sustaining a harvestable annual surplus of 0.5 million kg.*	*Walleye consumption advisories and restrictions are in place throughout the basin due to contaminant levels. Walleye reproduction has been negatively impacted by acid rain in the North Channel and Georgian Bay. Nutrient enrichment and sediment deposition from watershed erosion has had a negative impact on walleye spawning shoals in Saginaw Bay.*
Maintain Channel catfish as a prominent predator throughout its natural range while sustaining a harvestable annual surplus of 0.2 million kg.	*Channel catfish are under consumption restrictions due to contaminant levels in Saginaw Bay and southern Georgian Bay.*

Protect and enhance fish habitat and rehabilitate degraded habitats. *Achieve no net loss of the productive capacity of habitat supporting Lake Huron fish communities and restore damaged habitats.* *Support the reduction or elimination of contaminants.*	*Water quality throughout the Lake Huron basin has shown gradual improvement since the signing of the Great Lakes Water Quality Agreement in 1978. Eutrophication is a problem in a limited number of areas such as Saginaw Bay and tributary inflows along the southwest shore of the main basin. Acid rain and heavy metal contamination is still a localized issue in some parts of the North Channel and Georgian Bay. Atmospheric deposition of contaminants from outside the basin is an ongoing problem as well as the proliferation of exotic species acting as new vectors for bioaccumulation of contaminants. The discharge of ballast water contaminated with exotic species is a form of point source pollution that is not adequately regulated.*

Background:

Lake Huron is large and diverse with a complex geological setting which has had an influence on water quality in the basin. The lake is the second largest in surface area (59,000 km²/23,000 mi²) and third in volume (3,540 km³/850 mi³) among the Great Lakes (Beeton 1984). Its limnology is influenced by five geographic features which include two major inflows, the St. Marys River and the Straits of Mackinac, and three relatively discreet basins, the main basin, Georgian Bay and the North Channel (Beeton and Saylor 1995). In addition, the lake occupies the largest drainage basin (134,000 km²/51,700 mi²) of all the Great Lakes and has a relatively long residency time, with an average of 22 years being required for water to leave the basin (Bredin 2002).

Historically, the water quality of the basin was characteristic of a low nutrient, oligotrophic lake (Dobson et al. 1974). As a result of human settlement, water quality characteristics in the lake have changed, at least in the near shore areas. The basin currently supports a population of approximately 2.5 million people with most of the population density concentrated in the southern portion of the watershed (Bredin 2002). Although the Lake Huron watershed has a relatively low level of industrialization, the Saginaw Bay watershed is extensively farmed and supports a major metropolitan area comprised of Flint, Saginaw, and Bay City (Bredin 2002). Intense farming is also found along the east shore of the main basin. The remaining watershed has been developed to a lesser extent but has historically supported intensive resource extraction activities including timber harvest and mining (Sly and Munawar 1988).

Maintaining, protecting and improving water quality throughout the Lake Huron basin will promote the productivity and diversity of fish communities. Clean water also ensures additional benefits are incurred such as a healthy human environment and fish that are safe to eat.

Description of issues:

Water quality impairments in the Lake Huron basin as well as the other Great Lakes gained prominence in the 1970s primarily as a result of accelerated eutrophication resulting from excessive phosphorous loadings to the lakes (Neilson et al 1995). As well as contributing to the proliferation of nuisance algae (Jackson and Hardy 1982), eutrophication also had negative effects on fish populations by reducing oxygen levels which in turn led to declines in important food items such as the burrowing mayfly, *Hexagenia sp.* (Schneider et al. 1969). In Lake Huron the problem of eutrophication was most pronounced in Saginaw Bay, the St. Marys River, Spanish River, Severn Sound and Collingwood Harbour, all of which were identified as Areas of Concern (AOC) by the International Joint Commission (IJC). In response, the 1987 Great Lakes Water Quality Agreement (GLWQA) committed the United States and Canada to established target levels for phosphorous loadings for each of the lakes including Lake Huron (IJC 1989).

Since 1981, phosphorous loadings to Lake Huron have been below target levels with the exception of 1982 and 1985 (Neilson et al. 1995). Significant progress has also been made in reducing phosphorous loading in most of the AOCs. Two AOCs in Lake Huron, Collingwood Harbour and Severn Sound, have received a variety of measures aimed at reducing nutrient loading and have been formally delisted as AOCs (Environment Canada 2003). The Spanish River AOC has also responded to nutrient remediation efforts and has been recognized as an Area in Recovery, progressing to the delisting status (Environment Canada 2003). Some localized nutrient problems still exist in some of the AOCs, especially Saginaw Bay and other areas of intense agriculture activity such as the southeast shore of the main basin (Bredin 2002). The growth of cage aquaculture in parts of Georgian Bay and the North Channel (Gale 1999) as well as increased recreational and urban development in these areas has the potential to increase eutrophication problems. Jackson and Hamdy (1982) have suggested that a 1 ug/L increase in total phosphorus could result in nuisance growths of *Cladophora* in parts of Georgian Bay.

An associated water quality issue is sedimentation from shoreline erosion and tributaries. Sources of sediments entering the Lake Huron basin have increased since the 19th century due to deforestation, urbanization and agricultural activities (Edsall and Charlton 1997). Excessive sediment loading can result in the loss of water clarity and in turn limit aquatic plant growth, degrade spawning areas, decrease feeding efficiency for sight-feeding fish, and facilitate the transport of phosphorous, heavy metals, pesticides and other organic compounds (Edsall and Charlton 1997).

In parts of the Lake Huron basin, in particular northern and central Georgian Bay, water quality has been impacted by sulphur dioxide emissions originating from the Sudbury basin (Conroy et al. 1976; Loftus 1976). This part of the basin is situated on the Canadian Shield which has a poor buffering capacity making this area susceptible to acidic precipitation. In several lakes draining into this area, fish communities have been lost (Beamish and Harvey 1972). Walleye stocks were once abundant in the McGregor Bay area, in northern Georgian Bay. Their extirpation in addition to loss of several river spawning stocks in the area by the 1960s has been blamed on severe acid depressions during spring runoff periods (Olver et al. 1982; Hulsman et al. 1983). A marked improvement in water quality in acid-stressed waters in the Sudbury area, including northern Georgian Bay was noted in recent years (Keller and Pitbaldo 1986; Keller et al. 1986). Impaired

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water quality due to low pH and heavy metals in some bays and inlets of Georgian Bay may still be adversely affecting fish communities (Johnson 1991).

Chemical contaminants have long been identified as having a negative impact on fish communities in Lake Huron (Berst and Spangler 1973). Over 360 anthropogenic chemicals have been identified in the Great Lakes with many of these being found in quantities that are dangerous to aquatic organisms (Whittle 1998). The most dangerous of these chemicals affect aquatic organisms in a number of ways including reproductive failure, developmental abnormalities, adult and embryonic mortality, malignancies, carcinogenic effects, neurobehavioural deficiencies, and genetic disruption (Beeton et al. 1999). The Lake Huron basin is susceptible to these contaminants even though many of them originate from outside the watershed. The large watershed and surface area combined with long retention times are features that contribute to the delivery and retention of pollutants (Bredin 2002). One recent study has suggested a link between dioxin contamination and the collapse of lake trout in some parts of the Great Lakes (Cook et al. 2003).

Negative consequences of the buildup of contaminants in the Lake Huron ecosystem are the restrictions on or advisories to limit consumption of fish for reasons of human health concerns. Across the Great Lakes, contaminants such as PCB, DDT, dieldrin, polychlorinated dioxins and other pesticides and industrial chemicals have been identified in fish, often at concentrations which exceed standards for human consumption (Hasselberg and Seely 1982; Devault 1985). Many of the contaminants bioaccumulate and biomagnify in the food chain and as a result are found in high concentrations in some of the top fish predators such as lake trout and walleyes. Fish consumption advisories due to contaminant levels are in place for a majority of fish species throughout the Lake Huron basin (Bredin 2002).

Waste heat production and radioactive contamination were determined to be potential environmental problems associated with nuclear generating stations in the Lake Huron basin as early as the 1970s (Berst and Spangler 1972). The Bruce Nuclear Generating Station, situated along the eastern shore of the main basin, has been in operation since the 1960s (Wismer 1999) and has recently increased its generating capacity with the prospect of further increases being proposed. Thermal discharges attract fish (Spigarelli et al. 1982; Haynes et al. 1989) and make them more vulnerable to exploitation (Wismer 1980, 1982). As well, some fish like gizzard shad and channel catfish may experience loss of condition due to winter residency in thermal outflows (Rattie et al. 1986).

Summary of current and historic data:

Information on water quality and associated effects on fish communities in Lake Huron can be found in a variety of sources. Early reviews of water quality and fisheries on Lake Huron focused primarily on the issues of cultural eutrophication and to a lesser extent on chemical contamination (Berst and Spangler 1974). More recent reviews have included the myriad of existing and emerging water quality issues in an ecosystem context (Bredin 2002).

The Michigan Office of the Great Lakes, Department of Environmental Quality (MDEQ), in partnership with the U.S. Environmental Protection Agency (USEPA), undertook the development of a Lake Huron Initiative Action Plan in 2000 with an update in 2002 (Bredin 2002). The purpose of the Lake Huron Initiative (LHI) was to identify environmental/natural resource issues of importance and devise an action plan to deal with them (Bredin 2002). One of the key issues identified in the LHI Action Plan dealt with critical pollutants and use impairments, particularly those dealing with fish or wildlife consumption and degradation of fish or wildlife habitat (Bredin 2002).

The following discussion will focus on information in the LHI Action Plan dealing with critical pollutants and trends in fish communities from the Lake Huron basin. A list of critical pollutants, partitioned into three categories including priority pollutants, pollutants of concern, and emerging pollutants, affecting fish communities in Lake Huron can be found in Table 3. These categories reflect the significance of each pollutant, with priority pollutants consisting of those that violate the most stringent Federal/State water quality standards or exceed the Michigan Department of Community Health (MDCH) or OMOE Sport Fish Consumption Guidelines, pollutants of concern being associated with regional or local impairments and emerging pollutants comprising those that have the potential to impact the physical or biological integrity of Lake Huron (Bredin 2002).

Critical pollutants affecting Lake Huron fish include PCBs, Chlordane, Dioxins, Mercury, Toxaphene, DDT and PBBs (Bredin 2002). A variety of methods are used to monitor the level of these contaminants in fish. Because many of these contaminants bioaccumulate and biomagnify in the food chain, predatory species such as lake trout and walleye are excellent indicators of these contaminants in the aquatic ecosystem (Whittle 1998). The U.S. Fish and Wildlife Service has been monitoring whole fish PCB levels in lake trout from Lake Huron since 1977, and have observed a significant decline in levels during the 1980s with a leveling off in the 1990s (Morse 1996: DeVault et al. 1996). Similar declines in the levels of DDT, chlordane, dioxins, and mercury have also been observed (Bredin 2002). For walleyes, mercury concentrations have increased in Saginaw Bay since 1990 but have remained stable in Thunder Bay (Day 2000). For some of these contaminants such as PCBs current levels in lake trout still exceed those recommended in the GLWQA (IJC 1989).

The results from edible portion monitoring of fish compared with the previously discussed whole fish monitoring has revealed that PCB, mercury, dioxin, chlordane and toxaphene burdens are still a concern for many fish from Lake Huron. A majority of samples collected throughout the Lake Huron basin and examined for PCB levels have resulted in consumption advisories being implemented by both the MDCH and OMOE for at least 15 species of fish. Consumption advisories due to elevated levels of toxaphene, mercury and dioxin are more variable and restricted to fewer areas and locations (Bredin 2002). The Saginaw Bay area has consumption advisories due to elevated levels of dioxin, DDT and PBB (Bredin 2002). In all, advisories restricting the amount and frequency of consumption are in effect throughout the Lake Huron basin for Chinook salmon, coho salmon, brown trout, steelhead, walleye, burbot, lake trout, lake whitefish, rainbow trout, carp, catfish, northern pike, white bass, white perch, white sucker and yellow perch (Bredin 2002).

Additional contaminant monitoring using prey fish and caged fish is also conducted at a variety of locations in the Lake Huron basin. The Canadian Department of Fisheries and Oceans (DFO) has monitored contaminant trends in rainbow smelt, one of the primary prey fish in Lake Huron since 1977 (Bredin 2002). As with the monitoring of predators and sportfish, concentrations of PCBs, DDT, and mercury have declined significantly in smelt during the 1980s and leveled off in the 1990s (Devault et al. 1994). The U.S. Fish and Wildlife Service also conducts caged fish monitoring at a number of locations to determine contaminant sources. The Saginaw River and

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tributaries have been identified as relatively large sources of PCB, dioxin, DDT and PBB (Morse 1996; Day 2000).

Water quality issues still exist for several AOCs in the Lake Huron basin. The Saginaw Bay area is still impacted by contaminated sediments, non-point pollution sources, and phosphorous loading (Beeton and Saylor 1995); its Hexegenia mayflies have yet to recover. The Pine River, which drains into Saginaw Bay, suffers from fish consumption advisories for DDT and PBB (Bredin 2002). In the St. Marys River, contaminated sediments, municipal discharges, and non-point pollution are still sources of water quality problems (Bredin 2002).

The Bruce Nuclear Generating Station is subject to a comprehensive environmental effects monitoring program that has tracked ecological conditions at this site from 1961 to 1989 (Wismer 1999). The focus of the monitoring program was to detect the effects of cooling water withdrawal and discharge on local aquatic resources. The effects on the local fish community have been variable and species specific. Significant population level effects were observed for white sucker, lake chub, and smallmouth bass and involved temporary declines in abundance for white sucker, displacement of distribution away from the thermal plume for lake chub, and an increase in growth, reproduction and survival in smallmouth bass. The mortality of larval fish due to entrainment or impingement into intake screens was high for some native species such as trout perch and deepwater sculpin. Large, episodic impingement events for exotic prey species such as alewives, rainbow smelt and gizzard shad also occurred. Long-term effects on offshore resident fish such as round whitefish were unclear, with assessment netting revealing an increase in adult abundance but models forecasting declines in reproductive success due to increased temperatures on spawning areas.

Included in the environmental effects monitoring is the monitoring of cesium-137 and tritium concentrations in fish at this site. Cesium-137 levels have been declining since 1989, with commercially caught whitefish, chinook salmon, rainbow trout and lake trout having levels that did not differ significantly from background levels (La Marre 1999). Some species such as white and redhorse suckers and walleyes have cesium-137 levels that are several times higher than background levels. Tritium levels in fish have been decreasing since 1989 (LaMarre 1999). The LHI has identified tritium as an emerging critical pollutant, however, recent reviews of tritium levels in the area have indicated they are not likely causing long-term harmful effects on the environment or its biological diversity (Bird et al. 2000).

The use of indicators as a tool to communicate information about the environment and about human activities that affect it was brought forward at SOLEC 2000 and 2002 (Bredin 2002). A number of the proposed Great Lakes indicators are relevant to the Lake Huron basin. Several of the proposed indicators that have a bearing on water quality and fish include reproduction status of walleyes of Saginaw Bay, phosphorous concentrations and loading into the basin, contaminants in YOY spottail shiners, atmospheric deposition of toxic chemicals into the basin, toxic chemical concentrations in offshore waters, E.coli and fecal coliforms in nearshore waters, contaminants in edible fish tissue, radionuclide levels, sediment flowing into wetlands, rivermouth and tributary sediments and contaminants in sea lampreys (Bredin 2002).

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Priority areas and issues:

Water quality throughout the Lake Huron basin has improved over the last few decades to the benefit of the fish community. Some locations in the basin are still experiencing compromised water quality that is affecting fish production and throughout the basin contaminant burdens in many fish result in consumption advisories and restrictions. Addressing these sources of water quality impairment is needed in order to achieve the full range of benefits from a healthy aquatic ecosystem.

The following is a list of Priority Management Areas (PMAs) and some of their attributes:

Whole lake

- Determine atmospheric inputs of PCBs, Chlordane, dioxins, mercury, toxaphene,
- Determine rates of sediment and nutrient loading from tributaries

Saginaw Bay

- Identified as an AOC
- Fish reproduction identified as an impaired use
- Walleye reproduction has not recovered
- Need to monitor fish community response, particularly reproduction, to remedial actions
- Historically received inputs of critical pollutants
- Remedial work ongoing
- Need to reduce loadings of critical pollutants
- Sediment from watershed erosion is detrimental to fish reproduction
- Fish consumption advisories extensive
- Requires on-going contaminated sediment cleanups in the Saginaw and Pine Rivers
- Tributaries sources of critical pollutants (PCBs, dioxins, mercury, DDT)
- Need to continue support for local pollution prevention efforts through technology transfer and education

St. Marys River

- Identified as an AOC
- Source of critical contaminants (PCBs, mercury, heavy metals)
- Need for sediment assessment

Severn Sound

- Remediation efforts have reduced nutrient enrichment impacts
- Need to monitor fish community responses to improved water quality

Southern Georgian Bay

- Need to determine impact of local nutrient enrichment
- Investigate historic sources of woody debris and sediments

Central and northern Georgian Bay/North Channel

- Historically impacted by acid precipitation
- Historic resource extraction activities (logging, mining) have impacted localized areas
- Need to determine if water quality improvements will result in fish community responses
- Need to identify and monitor sources of mercury, heavy metals

Southeast main basin

- water quality problems (sediments, nutrients, bacteria) from tributaries entering the basin
- thermal plume from nuclear generating plant
- site of recent outbreaks of botulism mortality

Information and research needs:

The following is al list of information and research needs as they relate to this Environmental Objective:

- Continue existing program to reduce loadings of critical pollutants
- Evaluate effectiveness of existing programs for critical pollutants
- Monitor response of fish communities, particularly reproductive status, to remedial actions
- Support development of total mass daily loading assessments for tributaries, Saginaw Bay and Lake Huron
- Continue local restoration efforts in AOCs (Saginaw River/Bay, St. Marys River)
- Support atmospheric monitoring and research to identify sources and track reductions
- Determine impact of atmospheric sources from outside the basin
- Forecast reductions in loadings as a result of existing activities
- Update pollutant loadings and contaminant levels
- Investigate new control programs to address identified sources and loadings
- Update tributary sediment and contaminant loading estimates
- Facilitate cooperative bi-national lakewide monitoring

- Refine beneficial use impairment assessment, including additional assessment of lake wide beneficial uses, especially chemical impacts on benthos and chemical and other factors influencing phytoplankton and zooplankton populations
- Develop monitoring strategy for indicators of critical contaminants
- Expand monitoring of lower trophic levels to track changes in the food web and contaminant uptake

Table 3. Critical Pollutants for Lake Huron (from Bredin 2002).

Category	Pollutant	Area	Indicator of Impairment
Priority Pollutant	PCBs	Lakewide	Fish tissue concentrations exceed Michigan Department of Community Health action levels or Ontario sport fish consumption guidelines and strong association with fish and wildlife deformities, and reproductive effects. Locations: Lake Huron (Michigan and Ontario), Saginaw Bay, Georgian Bay, North Channel, Thunder Bay, Au Sable River, Bad River, Caro Impoundment, Cass River, Cheboyganing Creek, Chippewa Reservoir, Flint River, Holloway Reservoir, Kawkawlin River, Kearsley Reservoir, Pine River, Lake Ponemah, Rifle River, Saginaw River, Sanford Lake, St. Marys River, Sebewaing River, Shiawassee River, Tawas River, Thompson Lake, Thread Creek, Tittabawassee River, Tobico Wetland, and Van Etten Lake.
Priority Pollutant	Chlordane	Lakewide	Fish tissue concentrations exceed the Michigan Department of Community Health action levels. Association with fish and wildlife deformities and reproductive effect. Location: Lake Huron (Michigan only).
Priority Pollutant	Dioxins	Lakewide	Fish tissue concentrations exceed the Michigan Department of Community Health action levels or Ontario sport fish consumption guidelines. In synergistic and additive combination with dioxin-like compounds, strong association with wildlife deformities and reproductive effects. Locations: Lake Huron (Michigan and Ontario), Georgian Bay, North Channel, Cass River, Saginaw River, Thunder Bay, and Tittabawassee River.
Priority Pollutant	Mercury	Local	Fish tissue concentrations exceed the Michigan Department of Community Health action levels or Ontario sport fish consumption guidelines. Locations: Lake Huron (Ontario only), Georgian Bay, North Channel, Au Sable River, Burt Lake, Cass River, Lake Fenton, Kearsley Impoundment, Lake Ponemah, Saginaw Bay, Sanford Lake, Thompson Lake, Van Etton Lake and St. Marys River (Michigan and Ontario).
Priority Pollutant	Toxaphene	Lakewide	Fish tissue concentrations exceed the Ontario sport fish consumption guidelines. Locations: Lake Huron, Georgian Bay, and North Channel and St. Marys River.
Priority Pollutant	Sediment/ Suspended Solids	Lakewide	Sediment causes harm through a number of actions including carrying pollutants downstream and, covering fish spawning and aquatic invertebrate habitat. Sediment is a problem in many Lake Huron streams in that it impedes fishery restoration by degrading spawning habitat and lowering or changing food web productivity, both in Lake Huron (especially Saginaw Bay) and in the tributaries.
Pollutant of Concern	DDT	Local	Fish tissue concentrations exceed the Michigan Department of Community Health action levels. Strong metabolites association with eggshell thinning and reproductive suppression in bald eagles. Association with wildlife deformities and reproductive effects. Location: Pine River (Michigan).
Pollutant of Concern	PBBs	Local	Fish tissue concentrations exceed the Michigan Department of Community Health action levels. Concern regarding carcinogenic and toxicity. Location: Pine River (Michigan).
Pollutant of Concern	Lead, Nickel, Copper, Zinc, Cadmium	Local	Sediments classified as heavily polluted by these metals in Lake Huron Areas of Concern in accordance with U.S. EPA sediment guidelines, 1977(a) and MOE "Guidelines for Open Water Disposal of Dredged Spoils". Associated with degradation of benthos and planktonic communities. In most cases, existing concentrations are due to historical discharges.
Pollutant of Concern	Nutrients - Phosphorus	Local	Eutrophication problems exist in localized areas throughout the basin. Location: Saginaw Bay.
Pollutant of Concern	Pathogens (E. coli)	Local	Beach postings from pathogens (coliform bacteria) in localized areas. Location: Saginaw Bay, southeast shore of Lake Huron, and southern Georgian Bay.

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