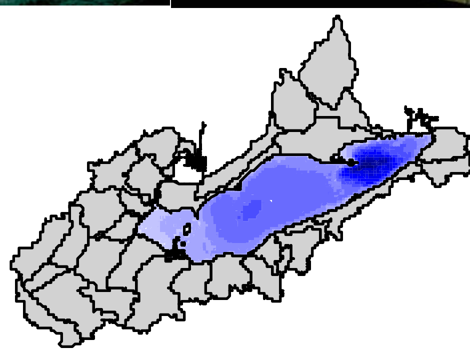
Lake Erie
Environmental Objectives

Report of the
Environmental Objectives Sub-Committee
of the
LAKE ERIE COMMITTEE
Great Lakes Fishery Commission
July, 2005



Subcommittee Members:

David Davies	*Ohio Department of Natural Resources (ret.)*
Bob Haas	*Michigan Department of Natural Resources*
Larry Halyk	*Ontario Ministry of Natural Resources*
Roger Kenyon	*Pennsylvania Fish and Boat Commission*
Scudder Mackey	*University of Windsor*
Jim Markham	*New York State Department of Environmental Conservation*
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EXECUTIVE SUMMARY

In accordance with the Joint Strategic Plan for Great Lakes Fisheries Management , fisheries managers from the five jurisdictions responsible for fisheries management in Lake Erie have established Fish Community Goals and Objectives (FCGOs) for the lake. The next step in the Joint Strategic Plan strategy is to identify the environmental conditions required to support achievement of FCGOs, and to define them as Environmental Objectives. Environmental problems or issues may occur lake-wide or at local scales. Problem resolution may require lake or basin wide recognition, to ensure that resources can be brought to bear at appropriate scales. Fisheries managers will act to achieve those objectives that fall within their operational responsibilities and advocate for the achievement of other objectives with appropriate agencies and lawmakers. The Lake Erie Lakewide Management Plan was recognized by the LEC in 2002 (Appendix 1) as important to achievement of the Environmental Objectives.

Environmental Objectives are intended to outline issues or conditions necessary to achieving habitat conditions that are important to achieving the Lake Erie Committees stated FCGOs. Habitat is defined in two ways – as an identifiable environmental feature (wetland, bay, rubble shoal) or as a place where conditions were suitable for a fish species (e.g. oxygen, transparency). Lake Erie is a mosaic of habitats whose distribution and characteristics depend on the current dynamic equilibrium of physical structuring forces interacting with substrates and the water column as well as biological structuring. Habitat units are lost or modified when the physical forces or processes are modified – e.g. shoreline structures interfere with coastal drift; modified hydrology of rivers changes the seasonality of flows.

In Lake Erie, ten Environmental Objectives have been identified to address achievement of the 13 FCGOs. These ten objectives identify important environmental structures, processes or conditions that must be addressed at a number of spatial scales to effect achievement of the FCGOs. Restoration of natural physical processes to the extent possible – i.e. natural (unfettered) coastal processes, and natural hydrological cycle in rivers, will promote recovery or re-creation of a more natural habitat mosaic and further allow the Lake Erie fish community to adapt to forecasted declines in water levels. Three objectives were defined in support of restoration of processes in Lake Erie: *1. Restore natural coastal systems and nearshore hydrological processes, 2. Restore natural hydrological functions in Lake Erie rivers and estuaries and 3. Recognize and anticipate natural water level changes and long-term effects of global climate change and incorporate these into management decisions*. These objectives have been written from a lakewide perspective, but actions needed to achieve them or to protect existing lake features (e.g. Long Point sediment nourishment by maintaining coastal drift) need to be conducted at a number of scales including lake basin, meso-scale, and local scales.

Four Environmental Objectives were identified that dealt with current conditions in Lake Erie as a whole or in specific PMAs (Priority Management Areas). These environmental conditions need to be addressed to permit recovery of specific components of the fish communities identified in the FCGOs. These objectives include: *1. Re-establish open water transparency consistent with mesotrophic conditions that are favorable to walleye in the central basin and areas of the eastern basin, 2. Maintain dissolved oxygen conditions necessary to complete all life history stages of fishes and aquatic invertebrates, 3. Restore submerged aquatic macrophyte* *communities in estuaries, embayments, and protected nearshore areas, and 4. Minimize the presence of contaminants in the aquatic environment such that the uptake of contaminants by fishes is significantly reduced.* These objectives recognize that the natural state of Lake Erie is mesotrophy, with moderate fertility, and typical water transparencies in the 3-5 m range, in contrast to other Great Lakes. If a favorable nutrient loading regime is maintained (current Great Lakes Water Quality Agreement objective, 11,000 MT/year of total P) then this will contribute to restoration of submerged aquatic macrophytes, maintenance of walleye populations in the central and eastern basins and help to maintain dissolved oxygen levels above critical levels in the open waters of Lake Erie. Secondly, these objectives recognize the need for a food web that is configured to maintain strong predation pressure on pelagic zooplankton. To achieve and maintain these conditions, it likely will be necessary to re-establish a native, open-water planktivore in the eastern basin, such as lake herring. Contaminants, although not as prevalent in Lake Erie as other Great Lakes, continue to be an issue that needs to be recognized. A strong network is in place to address the need for contaminant monitoring in Lake Erie's fish and the aquatic community, and this network has shown that that most food fishes are suitable for consumption. However, there are still some locations (AOCs) or size ranges of particular species that exceed contaminant objectives. The contaminant objective is provided in recognition of the need for continued work to identify and remediate sources, as well as provide impetus for Lake Erie fisheries managers to continue to interact with other regulatory agencies.

Three Environmental Objectives recognize that Lake Erie and the fish community continue to be negatively affected by human or biota mediated habitat degradation. These objectives include: *1. Halt cumulative incremental loss and degradation of fish habitat and reverse, where possible, loss and degradation of fish habitat, 2. Improve access to spawning and nursery habitat in rivers and coastal wetlands for native and naturalized fish species, and 3. Prevent the unauthorized introduction and establishment of additional non-native biota into the Lake Erie basin, which have the capability to modify habitats in Lake Erie.* These three objectives recognize that, particularly in tributaries and nearshore areas, habitats continue to be degraded. Altering habitat by preventing access, through dams and dikes, continues to be a significant issue relative to achievement of FCGOs. Cumulative losses of habitat in nearshore areas continue to be an impediment to achievement of FCGOs. Additionally, the unauthorized introduction and establishment of non-native biota that have the capability to modify habitats is of concern and this objective recognizes this.

Our increasing knowledge of the finer detail of population structure has led to recognition that particular places are unique because sub-units of the population, or stocks, have adapted their life history to use of those places. Priority management areas were selected in recognition of the importance of specific locations relative to the recovery of depressed or extirpated fish stocks, to the fish community of Lake Erie. Ultimately, achievement of Environmental Objectives, initially at PMAs, and eventually at other identified locations, should lead to significant progress in achievement of FCGOs for Lake Erie. Achievement of these objectives, however, cannot be completed by fisheries managers alone. Fisheries managers must identify the ecological and economic benefits of targeted rehabilitation work, develop strategic alliances, and influence priorities for funding with other agencies working in the environmental management realm.

INTRODUCTION

The Joint Strategic Plan for Management of Great Lakes Fisheries was developed by member agencies of the Great Lakes Fishery Commission (GLFC) in 1980 as a commitment to inter-jurisdictional, coordinated, and ecosystem-based fisheries management.

The following common goal was established in Joint Strategic Plan for all Great Lakes:

> *"To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, cultural heritage, employment and income, and a healthy aquatic ecosystem" (GLFC 1980; 1997).*

The Joint Strategic Plan directed the Lake Committees to develop Fish Community Goals and Objectives (FCGOs) for each lake, to identify environmental issues that may impede achievement of the FCGOs, and to develop Environmental Objectives that would complement and facilitate the achievement of the FCGOs. Both the Great Lakes Water Quality Agreement (GLWQA) and the Joint Strategic Plan use the ecosystem approach. The GLWQA deals directly with water quality issues, environmental conditions, and ecological integrity. The Joint Strategic Plan exercise to establish fish community goals and objectives can provide some of the measures of progress towards recovery of ecological integrity associated with impacts from the GLWQA.

This document provides guidance to fishery and environmental management agencies in the form of descriptions of the various environmental conditions affecting Lake Erie fisheries resources (Figure 1) and conditions that are needed to ensure that Lake Erie's FCGOs will be achieved. Following the guiding principles outlined in the FCGOs, this document identifies critical environmental conditions that should be the premise for achievement of FCGOs. Additionally, this document provides examples of indicators of favorable conditions and provides policy, regulation, and strategic recommendations for achieving those conditions. Several position statements that address related aspects of Lake Erie habitat/environment have been issued by the Lake Erie Committee and are provided in the Appendix.

Methodology

Environmental Objectives (EOs) were derived directly from an evaluation of the FCGOs. Each Fish Community Objective (FCO) was examined critically to identify environmental conditions and processes necessary for realization. This included an evaluation of the various physical, chemical, and/or biological conditions or processes that either help or hinder the achievement of the FCO.

Many of the environmental problems and issues affecting the achievement of the FCGOs and associated EOs originate beyond the actual physical boundaries of Lake Erie. The scope of the EOs necessitates the consideration of a range of habitat types, including those associated with watersheds, tributaries, coastlines, and nearshore and open-lake areas of Lake Erie. A cornerstone in the development of the EOs is the development and application of a dynamic habitat paradigm that identifies recurring processes (or structures) that directly or indirectly shape environmental conditions to which aquatic communities respond. Another central concept in the development of the EOs is the stock concept (Ihssen et al. 1981) and, where appropriate, a stock perspective was used to identify the spatial scales of habitat that need to be addressed in each environmental objective.

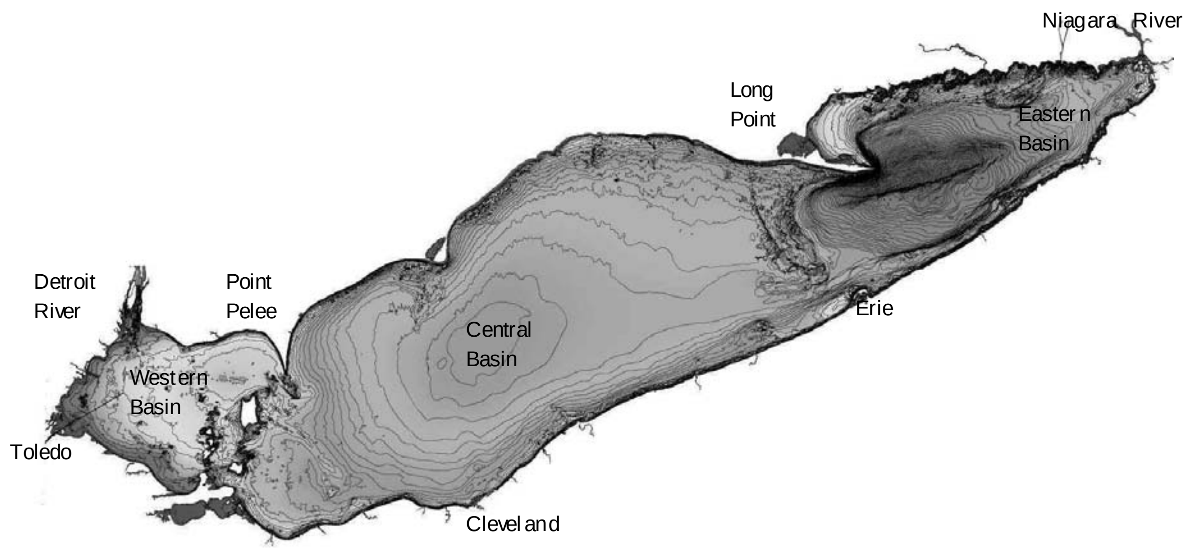

Figure 1. Area of focus for the Lake Erie Environmental Objectives, from the mouth of the Detroit River to the mouth of the Niagara River. Bathymetric 1-meter contour intervals are shown (National Geophysical Data Center 1998).

Fish Community Goals and Objectives: An Overview

A summary of the Lake Erie Fish Community Goals and Objectives (Ryan et al. 2003) is presented below to demonstrate the linkages between the Fish Community Goals and Objectives and the Environmental Objectives.

Lake Erie Goals

- To secure a balanced, predominantly cool-water fish community, with walleye as a key predator in the western basin, central basin, and the near-shore waters of the eastern basin, characterized by self-sustaining indigenous and naturalized species that occupy diverse habitats, provide valuable fisheries, and reflect a healthy ecosystem.

- To secure a predominately cold-water fish community in the deep, offshore waters of the eastern basin with lake trout and burbot as key predators.

Fish Community Objectives

- **Ecosystem Conditions**
  Maintain mesotrophic conditions (10-20 $\mu g \cdot L^{-1}$ phosphorus) that favor a dominance of cool-water organisms in the western, central, and nearshore waters of the eastern basins; summer water transparencies should range from 3-5 m (9.75-16.25 ft) in mesotrophic areas.

- **Productivity and Yield**
  Secure a potential annual sustainable harvest of 13.6-27.3 million kg (30-60 million lb) of highly valued fish.

- **Nearshore Habitat**
  Maintain nearshore habitats that can support high quality fisheries for smallmouth bass, northern pike, muskellunge, yellow perch, and walleye.

- **Riverine and Estuarine Habitat**
  Protect and restore self-sustaining, stream-spawning stocks of walleye, white bass, lake sturgeon, and rainbow trout.

- **Western Basin**
  Provide sustainable harvests of walleye, yellow perch, smallmouth bass, and other desired fishes.

- **Central Basin**
  Provide sustainable harvests of walleye, yellow perch, smallmouth bass, rainbow smelt, rainbow trout, and other desired fishes.

- **Eastern Basin**
  Provide sustainable harvests of walleye, smallmouth bass, yellow perch, whitefish, rainbow

smelt, lake trout, rainbow trout, and other salmonids; restore a self-sustaining population of lake trout to historical levels of abundance.

- **Contaminants**
  Reduce contaminants in all fish species to levels that require no advisory for human consumption and that cause no detrimental effects on fish-eating wildlife, fish behavior, fish productivity, and fish reproduction.

- **Fish Habitat**
  Protect, enhance, and restore fish habitat throughout the watershed to prevent degradation and foster restoration of the fish community.

- **Genetic Diversity**
  Maintain and promote genetic diversity by identifying, rehabilitating, conserving and/or protecting locally adapted stocks.

- **Rare, Threatened, and Endangered Species**
  Prevent extinction by protecting rare, threatened, and endangered fish species (e.g. lake sturgeon and lake herring) and their habitats.

- **Forage Fish**
  Maintain a diversity of forage fishes to support terminal predators and to sustain human use.

- **Food Web Structure**
  Manage the food web structure of Lake Erie to optimize production of highly valued fish species. Recognize the importance of *Diporeia* sp. and *Hexagenia* sp. as key species in the food web and as important indicators of habitat suitability.

Dynamic Habitat Paradigm

In order to describe the environmental conditions needed for the Lake Erie FCGOs to be achieved, we need to define aquatic habitat. Aquatic habitat can be described as any combination of a multitude of variables that define or delimit the space in which biota live (Sly and Busch 1992), but essentially is a set of physical and biological conditions within which a species can find all of the requirements to allow for successful completion of its life history (Jones et al. 1996). In most aquatic systems, we need to recognize that aquatic habitat is defined by its dynamic three-dimensional nature (Christie and Regier 1988) or stated alternatively, habitat is “probabilistic” at “site specific” scales (Sly and Busch 1992).

A unit of habitat may be flexibly defined as an environmental feature (e.g., water sorted cobble), a volume (e.g., a water mass with certain characteristics and location), a region of the water body (bay, basin), or a recurring landform/waterscape pattern (wetland), which may be anticipated to favor or support a stage in a life cycle of a species or a characteristic set of biota. Most importantly, aquatic habitat units are not necessarily defined by the fish species of interest themselves, but are adapted to by identified species through biological accommodation or stock development. Aquatic habitat units are created and maintained through the interaction of energy (climate and gravity) with broad-scale geologic, geomorphic, and hydrologic features on the landscape over varying spatial and temporal scales (Legendre and Demers 1984) (Figure 2). Moreover, these physical processes must result in habitat units that are repeatable in space and time such that biological accommodation or adaptation can occur (i.e., biological communities can co-evolve, adapt, and successfully use these habitats during various life stages, stock development, etc.) (Marshall and Ryan 1987). Repeatable characteristics include, but are not limited to seasonal changes in flow and temperature, hydraulic connectivity, substrate distribution, water levels, open-lake circulation patterns, productivity and availability of food supplies, refugia, and suitable spawning and nursery habitats. Some of these characteristics may remain relatively stable for decades, while others are in a state of continual flux. Achievement of FCGOs will require attention to such flexibly defined habitat units, and to how these key habitats directly link to fish life histories.

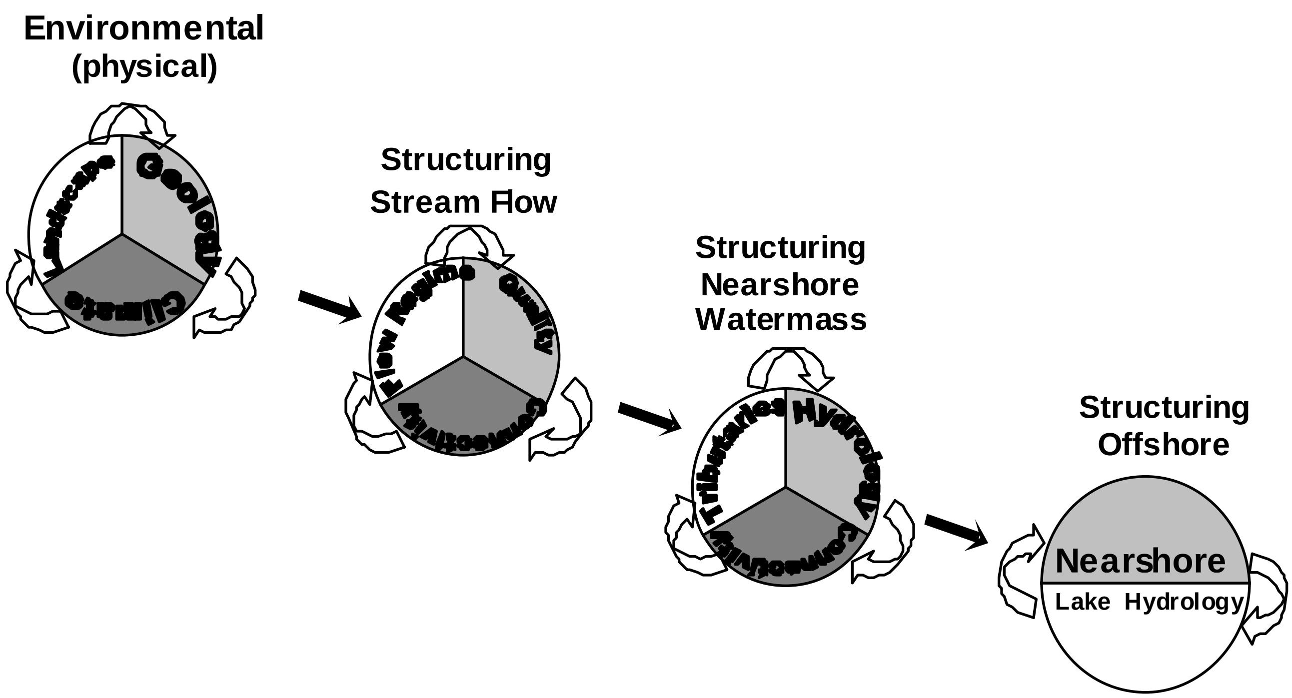

Figure 2. Physical controls and structuring forces on Lake Erie basin aquatic habitat.

As indicated above, fish stock development is an integral part of identifying environmental conditions conducive to achievement of the FCGOs. A stock of fish can be defined generally as a sub-division of a population into more or less genetically distinct subunits that maintain and sustain themselves over time in likely different, definable areas (or habitat units). The stock concept has long been recognized as important in the management of many populations of exploited fish (Van Vooren 1978; Colby and Nepszy 1981; Ryder et al. 1981). Recognition of stocks is also important for enhancement of existing populations or re-establishment of lost components of the fish community (Van Vooren 1978; Saunders 1981; Gatt et al. 2003). The stock concept allows fisheries and environmental managers to identify geographic ranges of independently reproducing populations, as related to specific life history stages, and to pursue enhancement/rehabilitation opportunities within more manageable habitat areas. The likelihood of stock structure for many of Lake Erie's principle species can be inferred from maps of historical spawning areas (Goodyear et al. 1982), tagging data (Van Vooren 1978; Wolfert and Van Meter 1978; Colby and Nepszy 1981) and electrophoretic and genetic analyses (Stepien and Faber 1998).

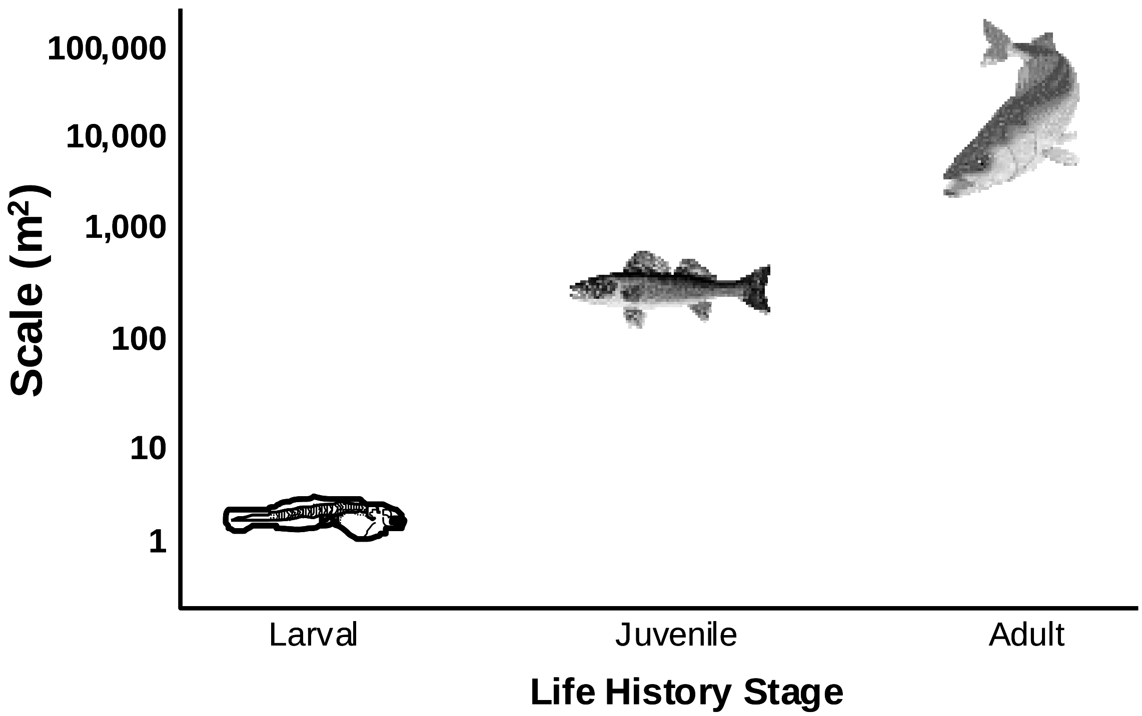

Figure 3. Lake Erie walleye life history stage-specific habitat scale.

Ultimately, to develop environmental objectives that assist fishery and environmental managers in achieving the FCGOs, we need to recognize that the species identified in the FCGOs are comprised of different stocks of fish that utilize different habitat units by life stage and season. These environments or habitat units can be maintained by physical forcing associated with hydrodynamics including tributary inflows, as well as nearshore and open-lake circulation patterns and can be altered by invasive species. The patterns of such processes are spatially and temporally dynamic, but are repeatable in space, time or both, such that stocks of fish have developed upon these patterns in physical processes. The quantity, characteristics, and continuing existence of these habitat units is dependent on maintenance of the hydrodynamic forces, as well as water quality and structural constraints within these units.

SCALES OF HABITAT

In order to develop Environmental Objectives, we must first understand fish-habitat relationships and recognize that habitat conditions at three spatial scales influence these fish-habitat relationships (Rabeni and Sowa 1996). There are three spatial scales that fish stocks in Lake Erie respond to including:

1. Local-scale instream habitat/stream flows as they influence spawning habitat and outwelling zones;
2. Meso-scale nearshore zones influenced by tributary inflows, bays, lake effect zones of rivers, and the interactions between these and coastal features; and
3. Broad-scale offshore water masses defined by gyres, open-lake hydrodynamics, and large-scale inflows.

Below is a summary of these spatial scales, processes that affect them, and potential impacts to important fish species.

Local-scale instream habitat/stream flows

Rivers are directly affected by watershed condition and land use practices. Landscape conditions affect the structuring forces of water quantity (flow regime), water quality, and connectivity of stream flow in river ecosystems. The natural flow regime (magnitude, timing, duration, frequency, and rate of change of water and energy within the watershed, e.g., Poff et al. 1997) evolved based on the connectivity of headwater streams and their drainage sources (surface runoff, through-flow, or ground-water driven systems). Anthropogenic changes in flow regime alter natural flow patterns, specifically by altering the frequency and magnitude of high water events and eliminating connections between the landscape and the aquatic system, with resulting adverse impacts on organisms that depend on these flows (i.e., esocids, some cyprinids, and sturgeon, e.g., Galat et al. 1998).

In Lake Erie, tributaries provide water, nutrients, and sediments that structure fish habitats. Tributaries provide important spawning and nursery habitat for walleye *Sander vitreus*, white bass *Morone chrysop*, lake sturgeon *Acipenser fulvescens*, and many other species. Tributary flows are the primary link between tributary spawning areas and nursery habitats (Mion et al. 1998). Tributary flows also extend into the lake and may influence nearshore and open-lake water quality, circulation, and water-mass characteristics (Figure 4). These seasonal flows connect spawning and nursery habitats and provide repeatable spatial and temporal habitat structure necessary for both riverine and shoal spawning walleye stocks to successfully reproduce in Lake Erie (e.g., Mion et al. 1998; Roseman 2000) and other Great Lakes systems. For example, Eshenroder (2004) has shown that the persistence of walleye stocks in the upper Great Lakes is linked to minimum tributary flow (100 m^3s^{-1}) and thermal regimes of tributary mouths. In Lake Erie, similar physical processes have contributed to walleye stock persistence (J. Tyson, Sandusky Fisheries Research Unit, Ohio Department of Natural Resources, Division of Wildlife, 305 E. Shoreline Drive, Sandusky, Ohio, 44870, unpubl. data.). The contributions of both river and shoal spawning walleye stocks to the walleye populations in Lake Erie is just one example of how the integration between lakes and rivers can influence fisheries stocks. Recent research by Ludsin and Stein (2001) has also shown that springtime tributary flows has a significant impact on yellow perch *Perca flavescens* year-class strength.

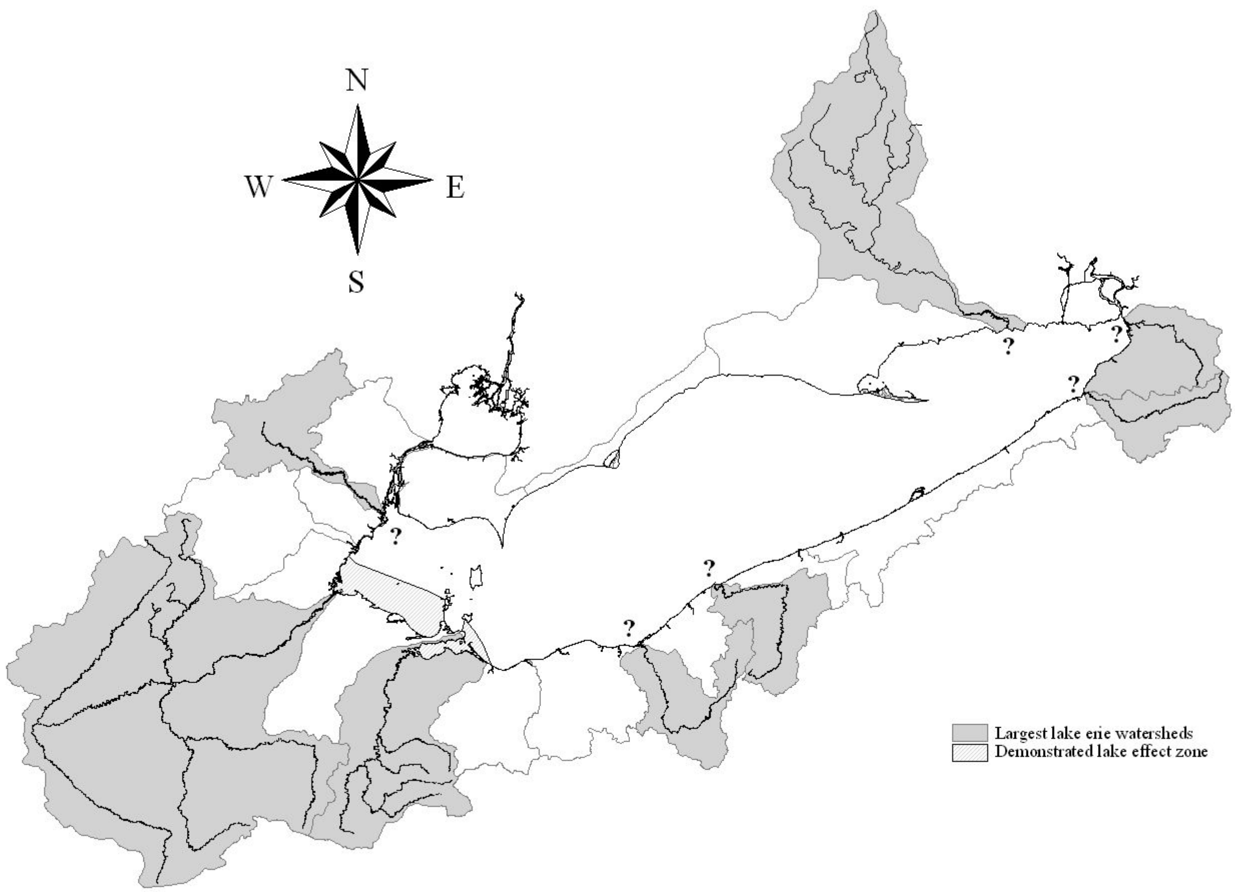

Figure 4. Lake Erie watershed. Highlighted watersheds are those that have an average discharge of >20 $m^3 \cdot s^{-1}$, and likely have significant lake affected zones. Cross-hatch areas are demonstrated outwelling zones (Tyson et al. 2001), while question marks indicate areas that likely are influenced by tributary outwelling.

Meso-scale habitat/nearshore water masses

The importance of meso-scale limnological features to fish population structure and recruitment variability has been recognized for many marine fish populations (Hjort 1914; Illes and Sinclair 1982; Nelson et al. 1977; Werner et al. 1997). For example, the "larval retention area" hypothesis for marine herring predicts that stock size will depend upon the volume of suitable larval habitat (temperature, clarity, and productivity etc.) (Illes and Sinclair 1982). In Lake Erie, these meso-scale features are also important structuring influences and are generally linked to tributaries and their associated plumes or outwelling zones. Plumes are the locations where carbon and nutrient outwelling from the tributaries create special habitat zones in which water transparency and temperature are favorable for survival of many larval fish (Mitsch et al. 1998; Odum 1968). Spawning areas in rivers and wetlands are generally linked to nursery areas through movement of water from tributaries to retention areas.

In a more open lake setting, larval retention areas may depend upon the dynamic interactions between stream flow and along-shore currents with coastal features. For example, the Grand River Ontario drains a large fraction of southwestern Ontario and influences a large area of the lake that extends well past its point of discharge. Two walleye stocks found there are associated with different spawning areas: one using typical habitat in the Grand River itself and another using nearshore reefs in the outwelling zone (C. Wilson, Aquatic Biodiversity and Conservation, Ontario Ministry of Natural Resources, Trent University, 1600 West Bank Drive, Peterborough, Ontario, CANADA, K9J 8N8, unpubl. data). Nearshore areas of western Lake Erie, especially embayments and protected coves, are known to provide suitable habitat for larval and juvenile walleye, yellow perch, and other species. Studies examining pelagic larval distribution in the western basin identified annual repeatable patterns in larval fish distribution that were typically associated with patches of high zooplankton density, high water temperature, reduced transparency, and high abundance of larval forage fish (Ludsin 2000; Mion et al. 1998; Roseman 2000).

Broad-scale habitat/offshore water masses

Lake Erie is comprised of three basins with distinct geophysical, chemical , and hydraulic properties that provide very different environmental conditions to support aquatic food webs. In the western basin, two distinct water masses predominantly influence the physical and biological conditions in the basin. These water masses are defined by river inflows (Detroit and Maumee Rivers) (Tyson et al. 2001). The Detroit River mass largely originates from the upper Great Lakes, enters Lake Erie from the northwest, and flows easterly along the northern portion of the basin. The Maumee River drains a large, agricultural watershed in northern Ohio, Indiana, and Michigan and flows easterly along the southern shore. These discrete water masses are generally persistent, repeatable, and homogenous (Charlton 1987; J. Tyson, Sandusky Fisheries Research Unit, Ohio Department of Natural Resources, Division of Wildlife, 305 E. Shoreline Drive, Sandusky, Ohio, 44870, unpubl. data.). Tyson (unpubl. data) also showed that plankton and benthic fish communities differed between these discrete water masses. The central basin has two dominant gyres east to west demarcated by Pointe-Aux-Pins. The western gyre typically circulates counter-clockwise, while the eastern gyre generally circulates in a clockwise direction. Apparent differences in chlorophyll and chlorphyll:total phosphorus ratios demonstrate patterns similar to those associated with the two different water masses in the central basin (Charlton et al. 1999). The eastern basin also appears to be structured by two dominant gyres, one along the north shore and one along the south shore, demarcated by the extension of Long Point (Mullen 1980; Saylor and Miller 1987), and these two gyres demonstrate discretely different water quality and plankton community characteristics.

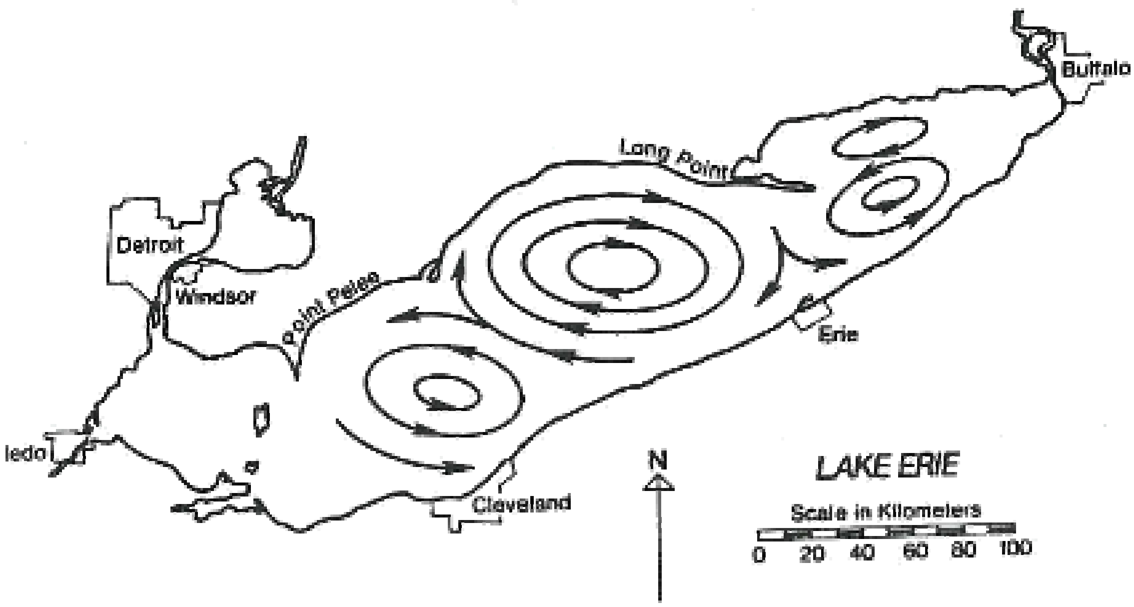

Figure 5. Dominant water circulation patterns observed in Lake Erie (reproduced from Saylor and Miller 1987).

The Environmental Objectives for Lake Erie incorporate the above dynamic habitat paradigm with identifiable habitat units, the fish stock concept, and spatial scaling issues. The following is a list of environmental objectives for Lake Erie that incorporates these concepts.

LAKE ERIE ENVIRONMENTAL OBJECTIVES

- **Water Levels and Climate Change**
  Recognize and anticipate natural water level changes and long-term effects of global climate change and incorporate into management decisions;

- **Coastal and Shoreline Processes**
  Restore natural coastal systems and nearshore hydrological processes;

- **Rivers and Estuaries**
  Restore natural hydrological functions in Lake Erie rivers and estuaries;

- **Open Water Transparency**
  Re-establish open water transparency consistent with mesotrophic conditions that are favorable to walleye in the central basin and areas of the eastern basin;

- **Dissolved Oxygen**
  Maintain dissolved oxygen conditions necessary to complete all life history stages of fishes and aquatic invertebrates;

- **Wetlands and Submerged Macrophytes**
  Restore submerged macrophyte communities in estuaries and embayments and protected nearshore areas;

- **Contaminants**
  Minimize the presence of contaminants in the aquatic environment such that the uptake of contaminants by fishes is significantly reduced;

- **Fish Habitat Protection**
  Halt cumulative incremental loss and degradation of fish habitat, and reverse where possible, loss and degradation of fish habitat;

- **Fish Access**
  Improve access to spawning and nursery habitat in rivers and coastal wetlands for native and naturalized fish species;

- **Habitat Impacts of Invasive Species**
  Prevent the unauthorized introduction and establishment of additional non-native biota into the Lake Erie basin, which have the capability to modify habitats in Lake Erie;

Support for Environmental Objectives

Each Environmental Objective is detailed further below with background information and a synopsis that defines the importance of the objective to components of the FCOs. Where possible, targets and endpoints, as well as suggested implementation actions and information needs are identified.

Priority Management Areas

The use of Priority Management Areas (PMAs) is a first step toward identifying geographic locations where specific actions associated with an Environmental Objective may be applied. Priority Management Areas are defined as locations within the watershed of Lake Erie, where rehabilitation of environmental conditions will contribute incrementally to achievement of Fish Community Objectives. Priority Management Areass identified in this document are selected to support rehabilitation of stocks and/or recovery of physical structuring forces to benefit species identified in the FCGOs. The list of PMAs in this document is not static, but is simply suggested as a starting point for rehabilitation of regionally and ecologically significant stocks of fish identified in the FCGOs.

Water Levels and Climate Change

Recognize and anticipate natural water level changes and long-term effects of global climate change and incorporate into management decisions

Synopsis

Lake Erie water levels change on short-term (daily and seasonally) and on long-term (annual, decadal) scales. Historically, the natural water level of the lake has varied over a range of 2-m (Lenters 2001; Quinn 2002; Lofgren et al. 2002). Changing water levels and the resulting shifts in shoreline location and the littoral zone have been implicated as having a large impact on structure, function, and productivity in aquatic systems (Chubb and Liston 1985). Given the low relief topography associated with Lake Erie, Lake St. Clair, and associated connecting channels, large expanses of shoreline areas typically become inundated and/or exposed with changes in water level. Hydraulic connectivity, water exchange, and fish access between coastal wetlands, embayments, and the open lake are directly related to the magnitude, timing, duration, frequency, and rate of change of these fluctuating water levels (S.D. Mackey, Habitat Solutions, 37045 North Ganster Road. Beach Park, Ill. 60087, pers. comm.).

Even though there is considerable uncertainty as to the impact of global climate change, a decline in Lake Erie water levels over the next several decades irrespective of cause (e.g., water withdrawals, diversions, modifications to connecting channels, or global climate change) will create new, natural shorelines. For example, the best estimates for the effects of global climate change over the next 70 years predict a 1-2 m decline in water levels of the Great Lakes (Lofgren et al. 2002; Mortsch and Quinn 1996; Lee et al. 1996), subsequently resulting in a reduction of the lakes' surface area and total volume and moving the shoreline distances of less than 1 km to as much as 6 km lakeward. Continuing development pressures threaten newly exposed areas, resulting in degradation and the risk of permanent loss of these critical fishery habitats and associated biodiversity as well as a loss of productive capacity.

Reductions in water levels could hydraulically isolate many high-quality wetland and estuarine areas that provide spawning, nursery, and forage habitat for Lake Erie and Lake St. Clair fish communities. Over 40% of Lake Erie's fish species are classified as wetland dependent or facultative wetland dependent. Moreover, reduced water levels will alter nearshore littoral and sub-littoral habitats, permanently altering benthic and fish community structure throughout Lake Erie and Lake St. Clair. The effects of lower water levels will not be limited to habitat, but may fundamentally affect seasonal timing and connectivity, food web dynamics, and the distribution, structure, composition and abundance of fish communities in Lake Erie, Lake St. Clair, and associated connecting channels (Casselman et al. 2002, Kling et al. 2003). For example a decrease in total water volume could lead to greater spatial overlap between predators and prey and could elevate predator-prey interactions (i.e. possibly increasing predation and/or feeding rates for some species at certain stages).

Under natural conditions, these habitat losses would be short-term as the ecosystem would adapt to a new water level regime and new wetlands and coastal/nearshore habitats would be created. However, anthropogenic modifications affecting the processes that create and maintain these critical habitats have limited the ability of the Lake Erie and Lake St. Clair ecosystems to recover and adapt. Modifications that alter the hydrodynamic environment can degrade habitat by changing substrate compositions, circulation patterns, and nutrient dynamics, which permit the establishment of new plant and animal assemblages and force the elimination of others. The permanent loss/change in the distribution of these critical wetland, estuarine, and nearshore habitats could have potential long-term consequences for Lake Erie and Lake St. Clair fisheries.

A warmer climate (e.g., Sousounis and Grover 2002) could also affect the thermal structure of Lake Erie causing changes in both lake chemistry and lake ecology. Climatic effects, such as lower precipitation and higher evaporation rates could result in lower water levels, higher surface water temperatures, a deeper and stronger thermocline, and a reduced water volume in the hypolimnion resulting in more frequent episodes of anoxia. Lower water levels have been implicated as one of the possible causes for the recent recurrence and expansion of the Lake Erie Central Basin "Dead Zone". Reduced water volumes in the hypolimnion, combined with selective feeding and altered nutrient cycling by invasive zebra/quagga mussels (*Dreissenid* spp.*)*, may increase decomposition rates and thereby rapidly deplete dissolved oxygen in the hypolimnion (Lam et al. 1987, 2002; Charlton and Milne 2004). Warmer water temperatures may yield an increase in potential secondary production rates and nutrient recycling, coupled with an increase in the prey demand required to meet those higher rates (Shuter and Meisner 1992; Shuter and Ing 1997; Brandt et al. 2002). Moreover, the rate of contaminant (mercury) accumulation in the food chain may increase due to increases in temperature and the relationship between temperature and mercury contamination in fish (Bodaly et al. 1993; Yediler and Jacobs 1995).

Warmer water temperatures, a deeper thermocline, and an expanded "dead zone" will potentially cause shifts in the distribution of both cold- and warm-water fishes in Lake Erie and its tributaries. The abundance of several species of important recreational and commercial fish (lake trout *Salvelinus namaycush*, walleye, and northern pike *Esox lucius*, and lake whitefish *Coregonus clupeaformis*) varies with the amount of thermally suitable habitat (Christie and Regier 1988; Lester et al. 2004). A warm thermal structure may cause a northward shift of boundaries for both warm- and cold-water fishes, affecting abundance, distribution, and sensitivity to exploitation (Minns and Moore 1992; McCormick and Fahnenstiel 1999; Casselman 2002; Kling et al. 2003). For example, coldwater fish (e.g., lake trout, rainbow trout *Oncorhynchus mykiss*, smelt *Osmerus mordax*) may be adversely impacted by a warmer thermal regime, while warm water fish (e.g., smallmouth bass *Micropterus dolomieu*, white bass, white perch *Morone americana*) will find a warm thermal regime hospitable (Casselman 2002).

Warming could relax the thermal constraints that have protected the Great Lakes in the past and increase the potential number of organisms that can successfully invade the lake (Mandrak 1989). Moreover, in response to these shifted thermal boundaries, zebra/quagga mussels, round gobies (*Neogobius melanostomus*), and other aquatic nuisance species could expand their existing ranges northward into the upper Great Lakes as well.

Targets and Endpoints

A precautionary approach is to limit, where possible, impediments to transitional habitats and establishment of a natural shoreline in response to changing water-level regimes. This would include the protection of areas with naturally occurring aquatic vegetation, coastal wetlands associated linkages between these wetlands and the open lake, and areas that support abiotic nearshore coastal processes and hydrology. These areas would include shallow embayments, open-lake shallow water areas (water depths less than 5 m), and adjacent coastal wetlands/estuarine areas that would be directly impacted by a 1-3 m drop in water level.

Implementation Actions

1. Promote general recognition that protection and restoration of coastal land-margin ecosystems is crucial to ecosystem rehabilitation and achievement of EOs and FCGOs.
2. Develop and use predictive models to quantify changes in habitat in response to changing water-level regimes. Identify existing and future habitat areas requiring protection and restoration. Identify future habitat areas that can be enhanced based upon changing water-level regimes.
3. Once identified, develop and implement conservation and protection Actions to protect potential refugia, transitional, and newly created habitats in coastal and nearshore areas from anthropogenic modification and/or degradation.
4. Adopt a proactive approach to fisheries that recognizes and anticipates potential long-term changes in water level and thermal conditions resulting from global climate change.

Information Needs

Irrespective of cause, we must understand how lower water levels will change basin and connecting channel configurations and flows and how this will alter the distribution of critical fisheries habitat, fish recruitment, and fish community structure in Lakes Erie and St. Clair. Moreover, additional efforts are needed to predict and assess the <u>future</u> location and extent of essential coastal, nearshore, and benthic habitats in response to varying lake-level and thermal regimes and likely consequences for the long-term sustainability of the food web and fish community. These efforts would include identification of threatened transitional habitats and anthropogenic factors or stressors that limit the ability of the fish community to adapt to changing lake-level regimes.

Coastal and Shoreline Processes

Restore natural coastal systems and nearshore hydrological processes

Synopsis

Nearshore areas provide spawning and nursery habitat for many Great Lakes fish species (Lane et al. 1996). These species exhibit a range of reproductive actions, requiring a diversity of habitat structures, environmental cues, and ecological interactions. Examples include: nesting in sheltered embayments by bass and other centrarchids, use of nearshore and offshore habitats by walleye during different life history stages, and accessibility of coastal and estuarine wetland spawning and nursery habitats (Casselman and Lewis 1996) for the success of Northern pike and muskellunge *Esox masquinongy* populations.

Coastal systems are comprised of diverse habitats (both terrestrial and aquatic) that are interconnected and dependent upon the natural physical processes that create and maintain them. Land-margin ecosystems are strongly influenced by coastal hydromodification, which alters physical processes and imposes constraints on aquatic habitat suitability, habitat utilization, and ultimately, productive capacity. Multiple stressors related to shoreline development have altered Great Lakes ecosystems (Kelso et al. 1996). Nearshore fish habitat has been lost or degraded at local sites along Lake Erie and associated tributaries due to agriculture, forestry, dredging and urban land use activities. Nearshore areas are especially susceptible to terrestrial landscape alterations due to proximity to shoreline areas and comparatively shallow waters that readily mix and distribute sediments and nutrients from terrestrial sources.

In 1993, approximately 50 % of the Lake Erie shoreline was protected by some type of man-made structure (IJC 1993). In Ohio, which has one of the most extensively developed shorelines in the Great Lakes, the percentage of protected shoreline ranges from 62% in Ashtabula County to 98% in Lucas County. The percentage of protected shoreline more than doubled in Ohio between 1970 and 2000 in response to increased shoreline development and erosion caused by near-record high Lake Erie water levels (Jonathan Fuller, Ohio Department. of Natural Resources, Division of Geological Survey, Lake Erie Geology Group, 1634 Sycamore Line, Sandusky, OH 44870). Impacts have been most pronounced along the southern and western shore of the western basin of Lake Erie, where dredging, shoreline armoring, infilling and diking of wetlands, and other shoreline modifications have eliminated land-margin connections, altered substrate and water-mass characteristics, and degraded spawning and nursery habitat for a wide variety of fish species. Erosion control and navigation structures such as breakwaters, jetties, and piers interrupt nearshore sediment transport processes, change nearshore water depths and energy dynamics, and alter nearshore circulation patterns and substrates. Given continuing development pressures on the Lake Erie shoreline, the percentage of protected shoreline will likely continue to increase over the next several decades.

Healthy wetlands are a valuable and intensively utilized fish habitat in the Great Lakes (Brazner and Beals 1997). Hardening the shoreline has resulted in the loss of access (connectivity) to coastal wetlands for obligate and facultative wetland species and loss of historically significant export production to the littoral zone and open lake. Direct and irreversible loss of coastal wetland and estuarine habitat is estimated to be about 80% lakewide (Snell 1987; Maynard and

Wilcox 1996). Degradation of remaining wetlands by infilling, dredging, diking, tributary loadings, and other physical, chemical, and biological perturbations is likely a major factor in restructuring the Lake Erie nearshore fish community.

Targets and Endpoints
Impediments to naturally functioning coastal processes and hydrology should be limited. The rate of shoreline armoring and hydro-modification must be reduced and "fish habitat friendly" designs must be implemented to protect and restore Lake Erie fish habitat. This includes the protection and restoration of areas with naturally occurring aquatic vegetation, coastal wetlands and associated linkages between these wetlands and the open lake, and areas that are critical to abiotic nearshore coastal processes and hydrology. These efforts should initially be focused on identified PMAs[1].

[1] Draft Lake Erie PMAs for coastal and shoreline processes:
- Metzger Marsh, Ohio
- Lackawanna waterfront, New York
- Sandusky Bay, Ohio
- Maumee Bay, Ohio
- Rondeau Bay, Ontario
- Grand River, Ontario
- Presque Isle Bay, Pennsylvania

Implementation Actions

1. Promote general recognition that protection and restoration of coastal land-margin ecosystems and processes that function in a dynamic equilibrium are crucial to ecosystem rehabilitation and achievement of EOs
2. Identify, delineate, and prioritize coastal systems for protection and/or restoration of fish habitat, including the identification of additional PMAs.
3. Develop "fish habitat friendly" designs and management Actions that minimize disturbance to natural processes, restore natural connectivity and fish habitat in nearshore and coastal areas, and promotes sustainable fish habitats in the future.

Information Needs
Managers need to develop a better scientific understanding of the physical processes that create and maintain nearshore and coastal fish habitats in Lake Erie. Abiotic factors, such as hydrology (flow, water-mass characteristics), geology (substrate), and energy (water depth, hydrodynamics) need to be integrated in order to identify and delineate critical coastal, littoral, and sub-littoral processes that affect nearshore habitat structure in Lake Erie. Collecting and integrating abiotic and biotic geo-spatial data by lake basin and coastal/nearshore segments will aid in defining critical nearshore and coastal habitats appropriate to community assemblages and life history of individual species. Assessments need to be made of the degree and type of shoreline armoring and changes to nearshore substrate, water depth, energy, connectivity, and the impact of armoring on coastal and shoreline processes relative to a more natural, less-disturbed historical condition. This will require collection of additional inventory data and establishment of new research initiatives focused on linkages between biotic and abiotic characteristics within coastal

and nearshore zones.

Rivers and Estuaries

Restore natural hydrological functions in Lake Erie rivers and estuaries

Synopsis

Modification of abiotic processes from watershed impacts is probably the most widespread habitat problem affecting fish stocks dependent upon rivers and estuaries. The most significant water quality and habitat impacts are largely due to intensive row-crop agriculture (mainly corn and soybeans), impervious soils (high rates of surface run-off), and a rapidly developing urban and industrial landscape. Urban and agricultural land uses have modified flow regimes at the watershed scale and increased sediment and nutrient loading to virtually all Lake Erie tributaries, Altered flow regimes have also increased peak flows, lowered base flows, and increased turbidity.

In addition, extensive channel and floodplain modifications (diking and channelization) have effectively isolated the tributaries from their floodplains (Baker et al. 2004). Channel modifications degrade the quality of spawning and nursery habitats in upstream reaches of estuarine wetlands and cut off access to seasonal floodplain pools located in riverine riparian zones and coastal wetlands. In many cases, potential upstream spawning and nursery habitat in rivers are isolated by dams (e.g., Grand River, Ontario; Sandusky and Maumee Rivers, Ohio). Riparian wetlands in major rivers have been filled or excavated for marinas and the rivers often flow between steel retaining walls and/or armor-stone breakwaters. Dissolved oxygen concentrations are unfavorable in the lower reaches of some tributaries and their lake effect zones (Buffalo River, Grand River, Cuyahoga River, Maumee River). Resident fish associations in these habitats have low indices of biotic integrity because they are dominated by tolerant species (Thoma 1999). Restoration of riparian and flow-through wetlands in the tributaries would improve habitat structure and water quality in rivers (Mitsch et al. 1998; Wang and Mitsch 1999).

Ecological restoration of river and estuary habitats requires that we manage physical hydrology and sediment dynamics at watershed and landscape scales by restoring desirable landscape conditions to support recovery of natural flow regimes and hydraulic connectivity. A dynamic equilibrium exists between the interaction of discharge (flow regime), channel slope, and the available sediments that create and maintain habitat units for fish and other biota in riverine and estuarine systems. Systematic changes in the flow regime affect stream power (i.e., its ability to grab/hold/move material) and modify the structure of habitat essential to the health of native species. Mion et al. (1998) found that recruitment of walleye from the Maumee River was affected by flow regime due to variations in the length of time it took for larvae to reach the lake. Eshenroder (2004) showed that the persistence of walleye stocks in the upper Great lakes is linked, in part, to minimum tributary flow (100 $m^3 \cdot s^{-1}$) and thermal structure at tributary mouths. Anthropogenic modifications that reduce minimum tributary flows and/or alter thermal structure within Lake Erie tributaries can adversely impact walleye stocks.

Targets and Endpoints

Where possible, impediments to naturally functioning riverine processes and hydrology should be limited so as to sustain critical fish habitats. Tributary flows need to be shifted towards more natural flow regimes, including restoration of natural connectivity between tributaries, estuaries, floodplains, and associated wetlands. Restoration efforts should include implementation of "fish habitat friendly" designs and management actions that minimize disturbance to natural hydrologic processes and restores/rehabilitates fish habitat in riverine and estuarine environments.

The Riverine and Estuarine Habitat FCO suggests that restoration of habitat for stream spawning stocks will exert some measurable control on year class strength. Sites can be prioritized based upon key species identified in the FCOs, principally walleye, lake sturgeon, and white bass. Watersheds with extant spawning stocks of these species should be protected or enhanced, while watersheds where stocks are ecologically extirpated or absent could be rehabilitated or restored. These efforts should initially be focused within identified PMAs[1].

[1] Draft Lake Erie PMAs for rivers and estuaries:

- Grand River, Ontario (walleye, lake sturgeon)
- Big Otter Creek, Ontario (walleye)
- Cattaraugus Creek, New York (walleye)
- Sandusky River, Ohio (walleye)
- Maumee River, Ohio (walleye, lake sturgeon)
- Portage River, Ohio (walleye)
- Huron River, Michigan (walleye)
- Detroit River, Michigan/Ontario (walleye, lake sturgeon, lake whitefish, white bass)
- Cuyahoga River, Ohio (walleye)

Implementation Actions

1. Promote general recognition that protection and restoration of landscapes and watersheds that promote natural flow regimes, reconnect tributaries to floodplains and estuaries, and enhance fish spawning and nursery habitats are crucial to ecosystem rehabilitation, and achievement of EOs.
2. Identify, delineate, and prioritize riverine and estuarine systems for protection and/or restoration of fish habitat, including the identification of additional PMAs.
3. Develop and use models to predict the degree of hydrologic alteration and associated fish habitat impacts. Use models to identify stressors and potential hydrologic and fish habitat improvements.
4. Develop "fish habitat friendly" designs and management strategies that minimize disturbance to natural processes; restores the natural connectivity between tributaries, estuaries, floodplains, and associated wetlands; and promotes sustainable fish habitats in the future.
5. Use an adaptive management approach to fisheries that recognizes and anticipates potential long-term changes in tributary flows and fish habitats.

Information Needs
Work is needed to analyze the current flow regimes of many of the Lake Erie tributaries, as well as work to define favorable flow regimes as recovery targets for each river system. The need for restoration work on the landscape should be estimated from historical analysis of landscape cover and resulting hydrograph, regional targets for landscape rehabilitation (Environment Canada 2004) or other models.

Open Water Transparency

Re-establish open water transparency consistent with mesotrophic conditions that are favorable to walleye in the central basin and areas of the eastern basin

Synopsis
The water transparency of 1929 reflected mesotrophic conditions (Fish et al. 1960). The water transparency of the central basin was indicative of mesotrophic conditions in the 1970s, although surface waters were predominantly nutrient rich (Charlton 1987). After the arrival of zebra mussels *Dreissena polymorpha* in the late 1980s, significant areas of the lake had very high water transparency values (Charlton 1994) and this likely has a profound influence of the distribution of habitat and the fish community in Lake Erie (Ryder 1977; Ryan et al. 1999).

A mesotrophic state can be described by a combination of phosphorus conditions, chlorophyll *a* levels, and water transparency (Carlson 1977). The latter two factors represent the amount of phytoplankton present and the effect that they have on light attenuation. The potential amount of phytoplankton present in the water column depends upon the amount of phosphorus present (Schindler 1977), but the relationship between phytoplankton abundance and phosphorus concentration can be affected by zooplankton grazing (Mazumder 1994) or *Dreissena* spp. (Millard et al. 1999) grazing in shallow waters.

The zooplankton grazing effect is most pronounced if large-bodied cladocerans are present. Recovery and maintenance of native fish planktivores (e.g., lake herring) could reduce zooplankton abundance, which could increase phytoplankton biomass (from reduced grazing), and decrease water transparency.

Targets and Endpoints
Total phosphorus, chlorophyll *a*, water transparency (Secchi data), and relevant food web data are used to track changes in water transparency and related factors in all basins through the Lower Trophic Level Sampling (LTLS) program administered by the Lake Erie Forage Task Group. The ratio of chlorophyll *a* to total phosphorus is an indicator of grazing pressure (Millard et al. 1999; Charlton et al. 1999) and needs to be monitored spatially, as the high transparency phenomenon is regional. Charlton et al. (1999) has mapped total phosphorus, transparency, and the chlorophyll to total phosphorus ratio for Lake Erie. The secchi disk range of 3-5 m (e.g., mesotrophic conditions) could be used as a target for achievement of this objective.

Implementation Actions

1. Promote general recognition that open-water transparency consistent with mesotrophic conditions is important to sustaining and re-establishing native fish community complex and

achievement of FCGOs.
2. Work closely with agencies that have water quality mandate, particularly EPA and Environment Canada in re-authorizing the Great Lakes Water Quality Agreement
3. Explore opportunities to re-establish and maintain native open-water plankivores which could influence open-water transparency.

Information Needs
Trend data addressing this information need (eg Charlton et al. 1999) should be integrated with current monitoring program data (LTLS program). The LTLS program provides very good temporal trend information regarding open-water transparency, chlorophyll *a*, and total phosphorus, however, the spatial coverage is limited, with each agency sampling only two stations. Broader spatial coverage is necessary to detect differences in open-water transparency and associated grazing pressure.

Dissolved Oxygen

Maintain dissolved oxygen conditions necessary to complete all life history stages of fishes and aquatic invertebrates

Synopsis
Tributary lake effect zones, estuaries, coastal wetlands, and embayments are generally much more productive than adjacent open water areas, due to warmer temperatures and nutrient input from tablelands. In some rivers, low water flows in summer combined with nutrient rich waters allows for development of unfavorable dissolved oxygen conditions, particularly in lower reaches of streams (Cuyahoga River, OH, BuffaloRiver, NY, Maumee River OH, and Grand River, ON). In Old Woman's Creek, Ohio, periodic reductions in oxygen are a diurnal event that coincides with photosynthesis and respiration cycles. In addition to the above areas mentioned, there are several areas that are vulnerable to unfavorable oxygen conditions and are critical to the maintenance of the food web, including:

- Lake effect zones, nutrient rich wetlands, and nearshore zones in all three basins which support crucial spawning and nursery habitat and are or were important production zones for *Hexagenia* spp.
- Adequate aerobic conditions are required in interstitial spaces in spawning and nursery areas throughout the incubation period (late fall to late spring) to ensure embryo survival and development in species like walleye, smallmouth bass, lake whitefish, and lake trout
- Adequate aerobic conditions in the hypolimnion of the central basin (including the "Pennsylvania Trench" connecting the eastern and central basins) is required for the maintenance of cold stenotherm species (both fish and crustacea)
- The deeper waters of the western basin provide habitat for fish and aquatic invertebrates, especially burrowing mayflies

Complete elimination of anoxia in the central basin is unprecedented and unrealistic, as there is evidence to indicate that the west-central basin has historically experienced periodic late summer anoxia (Delorme 1982; Charlton 1987; Reynoldson and Hamilton 1993). However, adequate dissolved oxygen conditions are required to ensure that the historic travel corridor is maintained between western basin spawning grounds and eastern basin adult feeding grounds for lake whitefish and walleye. Maintenance of this corridor will also be crucial to the distribution of fish and the restoration of extirpated lake herring stocks.

In the western basin, benthic anoxia that resulted in massive die-offs of *Hexagenia* spp. in the 1950s was first observed in river mouth areas before spreading throughout the entire western basin (Brit 1955; Manny 1991). Offshore benthic anoxia can occur in periods of reduced water column mixing or seiche driven movement of waters from the central basin into the western basin. Improved dissolved oxygen conditions in the western basin were at least partly responsible for the recovery of western basin *Hexagenia* spp. populations in the late 1990s (Krieger et al. 1996).

Targets and Endpoints
This objective will be achieved and maintained primarily by controlling tributary loadings of sediment and nutrients that cause oxygen depletion directly, or can stimulate primary production. Several PMAs, in the following areas, should be established where improvements can be made to nearshore aerobic conditions:

Cuyahoga River, Ohio
Maumee River and Bay, Ohio
Sandusky River and Bay, Ohio
Lower Grand River, Ontario
Huron River Estuary, Michigan
Buffalo River, New York

Davis (1975) developed a series of recommendations to provide protection for fish based on average values of incipient limiting dissolved oxygen levels:

Community	**Level A**	**Level B**	**Level C**
Salmonids	7.84 mg·L^{-1}	6.00 mg·L^{-1}	4.16 mg·L^{-1}
Mixed, with salmonids	7.27 mg·L^{-1}	5.26 mg·L^{-1}	3.25 mg·L^{-1}
Mixed, no salmonids	5.63 mg·L^{-1}	3.98 mg·L^{-1}	2.33 mg·L^{-1}

At Level A, few individuals will exhibit effects of low oxygen. At Level B, the average incipient limiting concentration, the average individual of a species will exhibit symptoms of oxygen distress. At Level C, a large portion of the community will be affected by low oxygen and the effects may be severe, particularly if the oxygen limitation is extended for more than a few hours. Davis (1975) indicated that these levels would provide protection for invertebrates. Acute mortality of *Hexagenia* spp. and fish eggs and larvae can be expected at dissolved oxygen levels below 5 mg·L^{-1}, but sub-lethal effects on growth and survival have been noted at higher levels (<7 mg·L^{-1}) (Ericksen 1963; Winter et al. 1996).

Implementation Stategies

1. The primary strategy needed to achieve this objective is to prevent further increases in loadings of sediments and nutrients. Nutrient loading above the capacity for receiving waters will be problematic. Since the signing of the Great Lakes Water Quality Agreement in 1972, phosphorus loadings (the primary nutrient promoting algal growth) have fallen to within target levels.
2. Other strategies to maintain adequate dissolved oxygen levels may include supplementation of base flow during periods of low dissolved oxygen through reservoir releases. Localized problem areas remain, however, because some waters are not able to adequately receive nutrients and maintain favorable dissolved oxygen conditions. These are mainly located at Remedial Action Plan Areas of Concern (e.g. Lower Cuyahoga River, OH, Wheatley Harbour, ON) and these are likely associated with the lack of lateral channel capacity to accept and process nutrients, as well as very low base flows during mid-summer.

Information Needs

Dissolved oxygen, biological oxygen demand, and benthic invertebrate populations should be monitored at each PMA. The dissolved oxygen conditions identified by Davis (1975) will also provide suitable habitat for most aquatic invertebrates. *Hexagenia* spp. are probably the most appropriate indicator of adequate dissolved oxygen conditions at nearshore locations, but other species may be needed as surrogates for *Hexagenia* spp. in their absence. *Diporeia hoyi* was selected as an indicater of good water quality conditions in the profundal zone (Ryder and Edwards 1985). Unfortunately, *Diporeia* is now believed to be regionally extinct in Lake Erie for reasons not directly related to dissolved oxygen conditions. Therefore, in deep profundal regions of Lake Erie, other biological indicators of dissolved oxygen conditions need to be developed.

Total suspended solids and temperature also require the development of targets and endpoints, consistent with the anticipated composition of the rehabilitated aquatic communities.

Coastal Wetlands and Submerged Macrophytes

Restore submerged macrophyte communities in estuaries and embayments and protected nearshore areas

Synopsis

Historically, most Lake Erie river mouths and sheltered embayments were nutrient rich, but did not suffer from extensive algae blooms or high sediment loads, or high turbidity. Instead, they had high secondary benthic productivity, due to favorable oxygen conditions and abundant aquatic vegetation that in turn, supported rich and diverse warm- and cool-water fish communities (Langlois 1954). Vegetated river mouths and embayments reflect structurally intact watershed and coastal ecosystems with the ability to efficiently process nutrient loads.

Loss of coastal emergent and submerged vegetation associated with changes in lake level, in addition to hydro-modification of the shoreline, changes in land-use, and the introduction of exotic species (common carp *Cyprinus carpio*) all contributed to elevated turbidity in many nearshore areas. The growth of submergent vegetation can be limited in these areas because of reduced light penetration caused by high turbidity. These changes have shifted the nearshore fish community composition from dominance by visual piscivores to dominance by benthivores and omnivores.

In some harbours and embayments (e.g., Leamington, ON, and Dunkirk, NY, Harbours, Presque Isle Bay, PA, Long Point Bay, ON, East Harbor, OH, Sandusky Bay, OH), increased clarity, likely the result of filtering activity by *Dreissena* spp., nutrient reductions, and recent declines in lake levels has stimulated growth of submerged aquatic vegetation. In turn, this has improved juvenile and adult habitat for a variety of important fishes, including smallmouth bass and other centrarchid species, northern pike, and yellow perch. Given that *Dreissena* spp. are recent invaders, they may yet undergo further changes in abundance and population structure. Whether changes to macrophyte communities at locations affected by *Dreissena* spp. will be permanent or stable is not known. However, with declines in lake levels predicted into the near term, re-establishment of submerged aquatic macrophytes and associated nearshore fish communities may be feasible.

Many estuarine wetlands and their associated embayments still lack diverse submerged macrophyte communities due to high rates of sedimentation and turbidity, an altered fish community, and lack of natural shorelines. Continued management of non-point source loading of sediment and nutrients, and surface water retention, is necessary to re-establish submerged aquatic macrophytes and restore coastal wetlands.

Targets and Endpoints

With reductions in sediment and nutrient loadings, the following PMAs should be targeted to restore persistent, diverse aquatic vegetation communities that are measurably healthier:

Maumee Bay, Ohio
Sandusky Bay, Ohio
Rondeau Bay, Ontario
Grand River, Ontario
Wheatley Harbour, Ontario
Big Creek Marsh, Ontario

In fact, all of these sites (with the exception of Big Creek Marsh) are currently the subject of formal rehabilitation programs that involve non-point source control of sediment and nutrients. The rehabilitation programs include the Maumee Remedial Action Plan, Sandusky River Basin TMDL program, Wheatley Harbour Remedial Action Plan, and the Lake Erie Lakewide Management Plan. Big Creek Marsh (the primary riverine wetland within the Long Point Marsh Complex) has a degraded submergent macrophyte community due to high suspended solid levels and requires a rehabilitation plan.

Aerial extent of vegetation coverage (%) or some surrogate (e.g., transparency) could be used as threshold criteria for recovery. Rooted macrophytes have been shown to be limited to the same depth as secchi disc transparency in Chesapeake Bay (Batiuk et al. 2000).

Implementation Actions

1. Promote general recognition that protection and restoration of lake connected macrophyte habitats are crucial to ecosystem rehabilitation, and achievement of EOs.
2. Actively pursue opportunities to re-establish submerged and emergent aquatic vegetation beds in areas that are likely to uncover during lower lake level stands.
3. Pursue the use of new technologies or engineered solutions, to assist in reduction of wave energy and reduction of sediment re-suspension in PMAs to promote revegetation.
4. Identify additional areas that are likely candidates for re-establishing aquatic vegetation based upon changes in lake level, and changes in nearshore transparency.

Information Needs
Field assessment or remote sensing to map current vegetation coverage is needed. Remote sensing technology needs to be further developed as a tool that will assist in the quantification of habitat. The Department of Fisheries and Oceans, Canada, with the assistance of Ontario Ministry of Natural Resources and Environment Canada, have conducted trials with Compact Aerial Spectrophotometric Imaging (CASI) in Long Point Bay. This technology shows the potential to be useful in the determination of specific submergent vegetation communities and substrate types to a depth of 5-m and incorporates other physical attributes. Other remote sensing tools that may prove useful include sidescan sonar, LandSat 5 & 7, MODIS, and AVHRR satellite images for determining extent and tracking change in submerged aquatic vegetation in the Lake Erie basin. Techniques for reducing sediment resuspension and submergent vegetation re-establishment in connected coastal wetlands.

Contaminants

Minimize the presence of contaminants in the aquatic environment such that the uptake of contaminants by fishes is significantly reduced

Synopsis
Presence of contaminants in fish flesh is currently a minor problem on Lake Erie compared to other Great Lakes. There have been few advisories for human consumption of commercial and sport fish and measurable impacts to fish eating birds (e.g., bald eagles) have been reduced over the last two decades. Continued presence of toxic compounds in the environment is a problem being dealt with through the Lake Erie Remedial Action Plan (RAP) at ten Areas of Concern (AOCs) (LaMP 2004).

Impacts of contamination by one, or a combination of, toxic compounds include increased mortality rates, changes in growth rates, and potential sub-lethal effects on productivity. Both direct and indirect impacts can disrupt the ecological linkages and function of the community. These effects have not been documented in Lake Erie. In addition, the presence of contaminants in sediments poses a rehabilitation challenge due to the risk of increased bioaccumulation through benthic food webs if they are not properly removed or separated from the food chain. However, since the invasion of dreissenids and round gobies and recovery of mayflies, the potential for contaminant uptake in the food chain has increased (Corkum et al. 1997).

Targets and Endpoints

This objective will be achieved when consumption advisories are no longer issued for any Lake Erie fish species. The ten AOCs identified to date can be considered as the PMAs for this Environmental Objective:
Detroit River (binational)
Raisin River, Michigan;
Maumee River, Ohio;
Black River, Ohio;
Cuyahoga River, Ohio;
Ashtabula River, Ohio;
Presque Isle, Pennsylvania;
Buffalo River, New York;
Wheatley Harbour, Ontario;
Niagara River (New York and Ontario).

RAP teams have or are currently developing strategies to deal with site specific contaminated sediment issues at most of these AOCs.

Implementation Actions

1. The strategy for addressing this objective involves continued measures to reduce loadings of toxic material and remedial measures to separate toxins from the food web at site specific contaminated sediment "hotspots". The strategies will be directed primarily at AOCs, where contaminant loadings and presence of contaminated sediments have been identified as impairments to beneficial use. Many of the ongoing loading problems are due to continued presence of combined sewer overflows (CSOs). Conversion of CSOs has been identified as a priority by RAP teams at several Lake Erie AOCs.
2. Prevention of bioaccumulation at existing contaminated sediment "hotspots" is a more challenging problem. Removing or capping of contaminated sediments is expensive and potentially disruptive to the environment. Some of these sites are wetlands, which may suffer from reduced ecological function after contaminant remediation. Treatment at contaminated sediment hotspots needs to be addressed on a case by case basis by RAP teams in consultation with the public.

Information Needs

There is a need to expand monitoring of the lower trophic levels to track changes in the food web and contaminant uptake. *Hexagenia* spp. populations, in particular, require further investigation as they have the potential to once again play a keystone role in the Lake Erie ecosystem after a 40-year absence (Tyson and Knight 2001). See Ciborowski (1998) for a summary of research needed to monitor contaminant uptake by *Hexagenia* spp.

Fish Habitat Protection

Halt cumulative incremental loss and degradation of fish habitat, and reverse where possible, loss and degradation of fish habitat

Synopsis

Fish habitat loss and degradation in the Lake Erie basin over the last 200 years has been extensive (Hartman 1973; Bolsenga and Herdendorf 1993; Halyk and Davies 1998). The most pronounced impacts have been to tributaries, coastal wetlands, and nearshore habitats that are crucial fish spawning, nursery, and food production areas. Loss of historic wetlands (which serve as critical nursery areas) in the Lake Erie basin is estimated to be approximately 80% (Snell 1987; Maynard and Wilcox 1996).

The pace of habitat loss and degradation has slowed dramatically in the past decade with the implementation of more comprehensive habitat protection legislation and policies in most jurisdictions, but incremental losses still occur both in Canada and the U.S. Some losses continue to occur as a result of activities that usually do not require land use permits (e.g., poorly planned agricultural and forest management activities) while others result from activities that are authorized with inadequate environmental safeguards or compliance monitoring.

Targets and Endpoints

Cumulative, incremental loss and degradation of fish habitat indicates that local scale cumulative degradations have negatively impacted the environmental conditions in Lake Erie, and compromised the functional and structural integrity of the fish community. Therefore, to address local-scale cumulative losses, agencies will need to implement local-scale enhancements. This, in concert with broad-scale habitat enhancements should contribute to reduction of habitat loss and degradation on Lake Erie.

Implementation Actions

1. Review the municipal, state/provincial, and federal statutes and policies dealing with environmental protection to ensure that they are comprehensive enough to address the potential for large and small scale incremental habitat losses at both the site specific and cumulative levels
2. Incorporate biological criteria relative to FCGO species into shoreline permitting process a local, state, and provincial level. Develop and mandate "fish habitat friendly" designs and management strategies relative to shoreline permitting that minimize disturbance to natural processes.
3. Ensure that sufficient manpower resources and logistical support are available to enforcement and technical staff to adequately monitor permitted activities for compliance to permit conditions and environmental protection legislation.

Information Needs

Additional research needs to be directed at impacts of shoreline development activity on productive capacity for FCO identified species in nearshore areas of Lake Erie. Additional information is needed on techniques for enhancement of nearshore fish habitat, and other possible fish habitat friendly shoreline development techniques.

Fish Access

Improve access to spawning and nursery habitat in rivers and coastal wetlands for native and naturalized fish species

Synopsis

Dams blocking access to suitable spawning and nursery habitat are a major factor limiting abundance of walleye, lake sturgeon, muskellunge, and northern pike in several Lake Erie tributaries. Diked wetlands prevent access to spawning grounds, nursery habitat, and feeding areas for a great number of nearshore, facultative and obligate wetland dependent fish species, many of which are rare, threatened, or endangered, such as spotted gar *Lepisosteus oculatus*. Fishway systems at diked wetlands or in tributaries do not address the use of the wetlands or tributaries by ichthyoplankton or juvenile fish that are susceptible to predation, and few fishway systems have been demonstrated to be completely effective.

Targets and Endpoints

This objective will be primarily achieved through dam removal efforts in tributaries, as well as through reconnection efforts in coastal wetlands. PMAs identified to date include:

Grand River, Ontario (walleye, lake sturgeon, rainbow trout)
Huron River, Michigan (walleye, rainbow trout)
Sandusky River, Ohio (walleye)
Metzger's Marsh, Ohio (warmwater and coolwater fishes, ichthyoplankton)
Sandusky Bay, Ohio
Sheldon's Marsh, Ohio

Implementation Actions

1. The strategy for achievement of this objective is relatively straightforward. Barriers that prevent access to suitable habitat should be removed where possible, or be modified so that fish can migrate around them. Easy two-way movement for fish will achieve this objective.
2. Identify opportunities for re-establishing fish access to coastal wetlands and tributaries at local and regional scales that maximize returns and probability of success relative to FCGO species.

3. Develop multi-agency partners to implement fish access and dam removals that address societal issues, as well as ecological and fish passage issues.
4. Promote research and development of fishways that allow for exclusion of non-desirable species, while allowing for free access of native and naturalized species.

Information Needs
Habitat quantification field studies in tributaries, estuaries, and coastal wetlands should be directed at candidate sites and designed in such a way that results can be applied to similar systems. Further work needs to be conducted on effectiveness of current fish passage structures.

Habitat Impacts of Invasive Species

Prevent the unauthorized introduction and establishment of additional non-native biota into the Lake Erie basin, which have the capability to modify habitats in Lake Erie.

Synopsis
This objective is focused upon those invasive species which have potential to modify the structure of habitat (habitat engineers), as illustrated by the effects of *Dreissena spp.*, Purple Loosestrife, *Phragmites spp.* and others.

Targets and Endpoints
New habitat-engineering species must be prevented from accessing the Great Lakes and Lake Erie. Prevention of the introduction of new habitat-engineering species can best be administered at various points of entry into the Lake Erie from other watersheds outside of the Great Lakes basin. PMAs identified to date include:

Welland Canal, Ontario
Portage Lakes, Ohio

Implementation Actions
1. Promote general recognition that NIS, especially those with habitat engineering potential, must be prevented from accessing the Great Lakes.
2. Continue to support research focussed to support identification of problem species, and prevention of access.

Information Needs
Further work needs to be completed in identification of non-indigenous species that can potentially establish and become nuisance species. Additional research needs to be conducted to determine effective strategies for reduction of importation of NIS into Lake Erie.

LINKAGE WITH OTHER HABITAT INITIATIVES IN LAKE ERIE

Fisheries management agencies around Lake Erie do not control all of the levers that must be operated to achieve Environmental Objectives. Fisheries managers must identify the ecological and economic benefits of targeted rehabilitation work, develop strategic alliances, and influence priorities for funding.

This process begins by identifying areas of common ground. The Environmental Objectives, like the Fish Community Goals and Objectives and the Lakewide Management Plan (LaMP) Habitat Strategy, share the recognition that watersheds are the relevant scale for aquatic management of ecological integrity and water quality.

Each EO has been developed to support the FCOs developed for Lake Erie. The objectives are interrelated and have been developed to benefit the entire Lake Erie ecosystem. The 13 FCOs can be grouped into four broad categories: Habitat Objectives, Biodiversity Objectives, Trophic Objectives and Basin Objectives (Fig. 5). Although EOs may be strongly linked to more than one FCO, only the primary linkages are displayed in the chart.

Habitat Objectives

Habitat objectives encompass fish, nearshore, riverine and estuarine habitat FCOs to provide diversity and resilience to support a stable, healthy ecosystem. To maintain, or improve, habitat in Lake Erie, managers must consider managing the presence and availability of contaminants and nutrients (see Trophic Objectives), and restoring natural hydrologic functions. The habitat objectives are also closely linked to Biodiversity Objectives since changes in physical habitat structure influence food web structure and vice versa.

Specific EOs directed at preventing losses and degradation of habitat and improving access to pristine natural habitats are vital to meeting habitat FCOs. Specific area habitat protection requires explicit objectives, therefore, hydrologic fluctuations (within a normal range) should be restored so that nearshore, riverine, and estuarine habitats are maintained.

Biodiversity Objectives

Biodiversity objectives encompass genetic diversity of populations and stocks that are healthy as well as those that are rare, threatened or endangered. Stocks and populations function at the food web level by helping to structure the entire community. The historic Lake Erie food web structure (including forage fish and invertebrates) was dominated by native species and was structured primarily by top predators such as walleye and lake trout (Ryan et al. 2003). Therefore, the community would benefit from fewer non-endemic species introductions (particularly unauthorized introductions) and a food web structure that is, once again, dominated by self-sustaining native populations.

Trophic Objectives

Trophic objectives are linked to the conditions in the lake, specifically the chemical and physical characteristics of the ecosystem that support and help to structure the fish community. Trophic objectives are not independent of other objectives, but rather are considered as components of habitat, biodiversity, and basin objectives that reflect a healthy ecosystem.

Basin Objectives

Basin objectives reflect basin productivity and yield that are derived from the fisheries in each basin. The basin objectives are influenced by chemical, physical, and biological objectives throughout the watershed and are grouped together in this category to reflect the management of Lake Erie fisheries and fish communities. Appropriate management of fisheries harvest and the restoration or rehabilitation of stocks at the watershed scale often requires efforts to be directed at specific locations, basins, or lake affected zones in the lake.

The LaMP, taking direction from the Great Lakes Water Quality Agreement, is a delivery vehicle used to address ecosystem level concerns. The LaMP Habitat Strategy was developed to specifically address habitat loss and alteration with an emphasis on “action”. The Habitat Strategy also provides a framework to guide and coordinate habitat protection and restoration work in the Lake Erie basin. Therefore, integration of the Environmental Objectives with the LaMP Habitat Strategy will facilitate achievement of desired outcomes for mutual benefit.

Working within the umbrella of the Lake Erie LaMP, efforts toward achieving the Environmental Objectives have a much better chance of succeeding. Although independent efforts will still occur, the coordinated efforts may benefit from synthesis with efforts to implement Remedial Action Plans (LaMP); develop Great Lakes indicators (State of the Lakes Ecosystem Conference); preserve land (The Nature Conservancy/Nature Conservancy of Canada); reduce pollution (Great Lakes Binational Toxics Strategy); identify and prioritize research needs (Lake Erie Millennium Plan); and implement fishery management plans including the Coordinated Percid Management Strategy, and Walleye and Yellow Perch Management Plans (Lake Erie Committee, Great Lakes Fishery Commission).

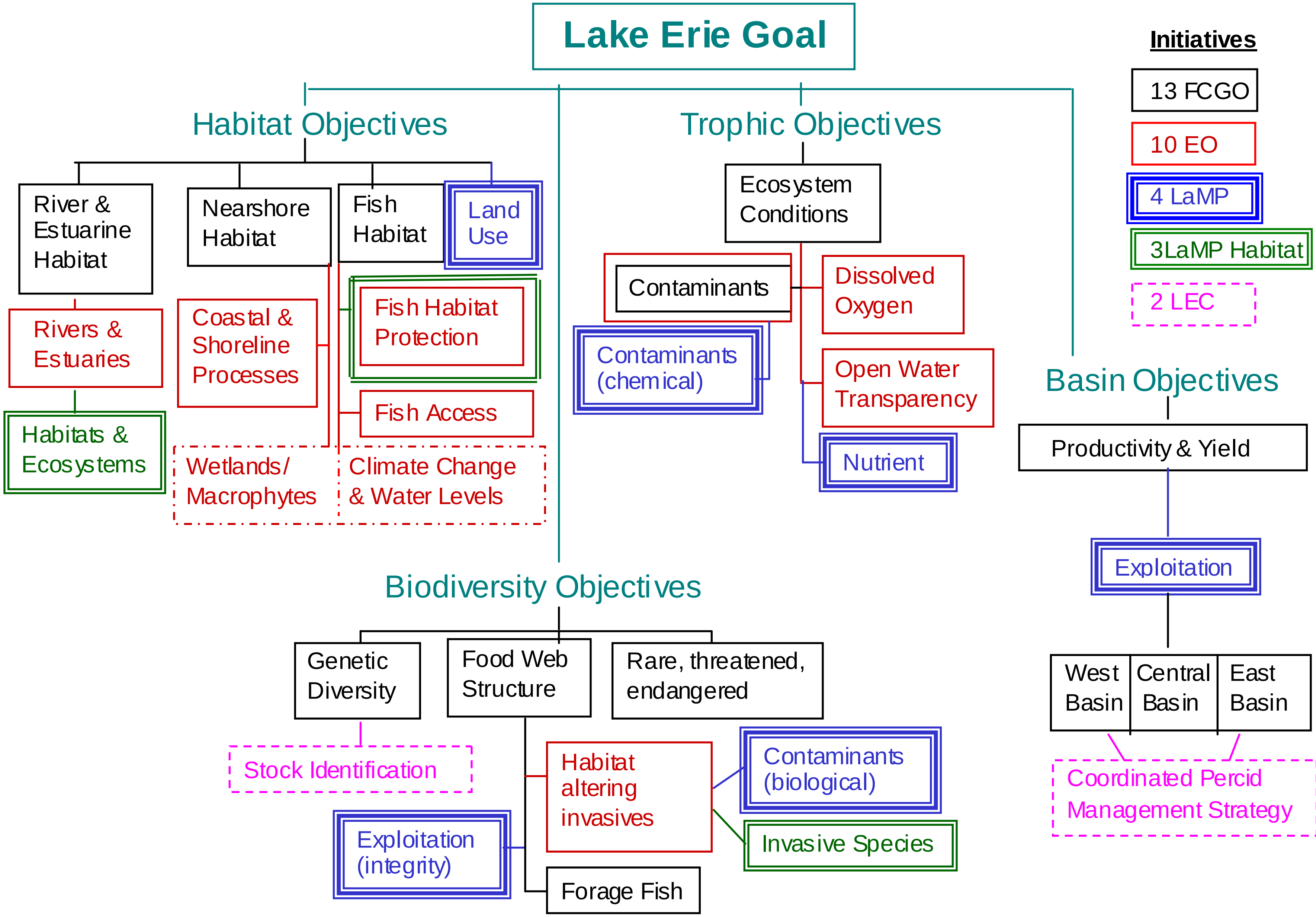

Figure 5. Lake Erie basin ecosystem objectives grouped to show alignment: Fish Community Objectives (black), Environmental Objectives (red), Lakewide Management Plan Objectives (LaMP) (blue), LaMP Habitat Strategy Objectives (green), and Lake Erie Committee initiatives (purple).

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APPENDIX 1: LAKE ERIE COMMITTEE POSITION STATEMENTS

Endorsed By:

The LAKE ERIE COMMITTEE,
Great Lakes Fishery Commission

Michigan Department of Natural Resources
New York Department of Environmental Conservation
Ohio Department of Natural Resources
Ontario Ministry of Natural Resources
Pennsylvania Fish and Boat Commission

LAKE ERIE COMMITTEE

POSITION STATEMENT

On

Productivity and Rainbow Smelt

As the Committee has pointed out for the past several years, the Lake Erie ecosystem has experienced declines in productivity that are most pronounced in the East Basin.

With respect to rainbow smelt, the Committee would like to point out that rainbow smelt is an exotic species that flourished in Lake Erie at a time when productivity was higher and predator populations were low. The conditions were well suited to smelt at that time. In the 1990s we have observed significant declines in smelt in the East Basin.

Given the changes that are occurring in the East Basin with respect to top-down and bottom-up effects, the expectation for a large, stable supply of smelt in the East Basin is not high. Should we experience further productivity declines in the Central Basin, similar concerns over smelt may emerge there as well.

Adopted:
Annual Lake Erie Committee Meeting
March 24, 1997
Ann Arbor, MI

LAKE ERIE COMMITTEE

POSITION STATEMENT

On

Lower Trophic Level Changes and Their Implications to Fish Community Composition and Productivity in Lake Erie

The Lake Erie Committee is committed to ensuring that the management of the very important fisheries of Lake Erie has been grounded in the best available science and information. The five jurisdictions along the lake have worked together in a highly successful and cooperative manner to ensure that the critical fisheries data series are maintained, and that the expertise in fisheries science is available.

The recent major changes occurring within the ecosystem of Lake Erie have major influence on the fish communities of the lake, and on the people who derive a living or enjoyment from them. Many of the changes underway appear to be driven by changes at the lower trophic levels of the ecosystem that have profound influence on both the composition and productivity of the fish communities within the lake. The collection of important scientific information at the lower trophic levels is an area beyond the immediate influence and expertise of the fisheries management agencies. However, as we attempt to understand the driving forces behind the changes in the lake, we find that very important data and knowledge at the lower trophic levels of the ecosystem is missing. The Committee feels that it is critical to come to a common scientific understanding of the causes of these changes in Lake Erie, and of their highly significant implications to fish community composition and productivity.

The Lake Erie Committee has been active in developing and adopting position statements on current issues and on issues the Committee believes will be important in the future. Most recently the LEC released a position statement on phosphorus management in Lake Erie, followed by a press release in February. The committee registered concern over the implications of further changes in phosphorus loadings to the lake until we come to a scientific understanding of how such changes will influence the composition and productivity of fish communities within the lake. The committee stands behind this statement and further wishes to make the point that phosphorus is a critical element in all freshwater ecosystems. Phosphorus is an essential nutrient, and finding the right balance is the important issue.

Phosphorus is only one influence at the lower trophic levels that needs to be examined as we attempt to understand the implications of the ecosystem change on Lake Erie fish communities. The Committee has called for immediate research concerning the changes within the ecosystem. Because of the complexity of the issue, this will require cooperation and collaboration among jurisdictions, agencies and Universities.

The five fishery management agencies represented on the Lake Erie Committee are very interested in supporting research initiatives that will improve our understanding of the changes within the Lake Erie ecosystem, and of their implications to fish community composition and productivity. All five agencies are prepared to assist such research by providing vessel time, facilities and staff for projects the LEC considers high priority in developing this scientific understanding and an ecosystem management approach for Lake Erie.

In the near future, the LEC intends to issue a clear statement of its priority research needs, and of the knowledge gaps that must be filled in order advance fishery management on Lake Erie. The five management agencies (Ontario Ministry of Natural Resources, Ohio Department of Natural Resources, Michigan Department of Natural Resources, Pennsylvania Fish and Boat Commission and New York State Department of Environmental Conservation) are committed to working with the various research institutions and other agencies to complete the necessary research. In the longer term, the five agencies wish to find means of ensuring that important data at all trophic levels are collected, and that the data series are maintained.

This is a major commitment on behalf of the agencies and we urge scientists and other agencies to take advantage of it.

Adopted:
Annual Lake Erie Committee Meeting
March 25-26, 1998
Niagara Falls, ON

LAKE ERIE COMMITTEE

POSITION STATEMENT

On

Phosphorus Management in Lake Erie

The Lake Erie Committee of the Great Lakes Fisheries Commission recognizes:

a) the many water quality and fisheries benefits achieved in Lake Erie from the phosphorus controls implemented under the auspices of the Great Lakes Water Quality Agreement,
b) that elevated phosphorus concentrations in some nearshore waters and tributaries of Lake Erie continue to contribute to problems of over-enrichment in some localized areas of the watershed,
c) that scientific understanding of the role of phosphorus in the food-web, fish production, fish community structure and other ecosystem dynamics of Lake Erie is currently inadequate to reliably predict the outcomes and consequences of changes in phosphorus management, and
d) that target loadings of phosphorus established within the Great Lakes Water Quality Agreement appear to have been achieved for Lake Erie, and that in some recent years loadings have been well under the target.

Given the incomplete scientific understanding of the role of phosphorus in the Lake Erie ecosystem, and the many problems that arose from over-enrichment of the lake during the 1960s and 1970s, the Lake Erie Committee suggests that it would be irresponsible to advocate adding phosphorus to Lake Erie until there is clear scientific evidence that this would be an appropriate strategy.

The Lake Erie Committee:

e) remains concerned over the rapid changes in the Lake Erie ecosystem and the unknown consequences of these changes to fish production and to the fish community structure of the lake,
f) remains concerned over the current incomplete scientific understanding of the ecosystem changes within the lake (the roles of exotic species and phosphorus in these changes are particularly poorly understood),
g) remains concerned over the potential consequences of further reductions in phosphorus loadings to the production and composition of Lake Erie's highly valued fish communities,
h) remains committed to its goal of managing walleye as a keystone species within a harmonic percid community,
i) remains committed to its objective of high quality mesotrophic conditions (and the associated phosphorus concentrations) in the western basin, central basin and nearshore waters of the eastern basin of Lake Erie, and
j) remains concerned over the inability of agencies to find resources that can be directed in

a concentrated fashion towards developing a sound understanding of the relationships of phosphorus to fish community dynamics in Lake Erie.

Given the incomplete scientific understanding of the relationships of phosphorus to fish production and fish community structure in Lake Erie, the Lake Erie Committee does not support deviation from the phosphorus targets established within the Great Lakes Water Quality Agreement until a thorough scientific review of target phosphorus concentrations for Lake Erie has been carried out in an ecosystem (rather than control) context. The Lake Erie Committee strongly encourages all relevant agencies to commit resources and work together to undertake such a review of phosphorus management on Lake Erie; this review must consider both water quality and fisheries issues.

Adopted:
Annual Lake Erie Committee Meeting
March 25-26, 1998
Niagara Falls, ON

LAKE ERIE COMMITTEE

POSITION STATEMENT

On

Structuring Native Fish Communities in the Twenty-first Century

The Lake Erie Committee (LEC) has recently finalized its Lake Erie fish community goal stating, in part, "To secure a balanced, largely coolwater fish community, based upon a foundation of self-sustaining indigenous and naturalized species that occupies diverse habitats, provides valuable fisheries and reflects a healthy Lake Erie ecosystem." The LEC has acknowledged the myriad of ecosystem disturbances over the past 165 years, including the reversal of nutrient enrichment during the past 30 years, which have resulted in the disparity between the current fish community and the goal.

The LEC's concern over the rapid reversal of nutrient enrichment resulted in the issuance, in March 1998, of a position statement concerning lower trophic level changes and their implications to fish community composition and productivity in Lake Erie, and an "interim" position statement on phosphorus management in Lake Erie. The recent changes in trophic status, coupled with introductions of nonindigenous species, may be causing a shift in the lake's energy flow from the pelagic zone to the benthic zone. In response, some native fish species, most notably whitefish and burbot, have experienced dramatic population increases. There has also been an obvious increase in abundance of small lake sturgeon and these fish community changes are creating much discussion within management agencies and among the publics for restoration of additional native fish species.

The LEC recognizes that reintroduction and restoration of indigenous fish species / stocks is a responsibility of the committee, which is comprised of representatives form the fishery management agencies of Ontario, Michigan, New York, Ohio, and Pennsylvania. The LEC accepts this responsibility and will actively, and in a timely manner, address the potential, feasibility, biological implications, commercial and recreational fishing impacts and costs associated with restoration and rehabilitation of species such as lake sturgeon, lake herring, sauger, etc. The LEC may actively seek partners in pursuing restoration efforts, but the LEC will implement and coordinate all reintroduction and restoration programs approved by the five jurisdictional management agencies.

Adopted:
Annual Lake Erie Committee Meeting
March 31 – April 1, 1999
Grand Island, NY

LAKE ERIE COMMITTEE

POSITION STATEMENT

On

Ballast Water Management

The Great Lakes have been subject to invasions of aquatic species since the settlement of the region by Europeans. Since the 1800's, over 140 non-native aquatic species have been introduced in the Great Lakes ecosystem. Some of these introductions have been intentional, and have resulted in benefits to society. However, the unplanned (ballast) introductions of non-native, harmful aquatic species have caused ecological, economic and public health impacts that threaten the value of Great Lake's resources.

Since 1959, most unintentional introductions of species into the Great Lakes are traceable to shipping. Approximately 85% of the vessels entering the St. Lawrence Seaway have "NOBOB"(No Ballast On Board) status and are exempt from laws requiring a high-seas exchange of ballast water. However, these vessels contain residual ballast water, sediment and sludge totaling several metric tons, which is later discharged in the course of changing cargoes. The total amount of ballast dumped into the Great Lakes is approximately six million metric tons per year. Since this ballast is not presently treated or filtered, non-native aquatic organisms can survive the journey across oceans from fresh water shipping ports around the world – to be discarded alive in Great Lakes waters via ballasting and deballasting.

Several non-native, and very destructive organisms are believed to have entered the Great Lakes via ballast in the past 15 years including: zebra mussels, round gobies, European ruffe and Russian water flea. All of these species have had profound influences on native species and food webs. *Diporeia*, an important food item of young lake trout and yellow perch has declined substantially in SE Lake MI due to zebra mussel filtration. Zebra mussels alone have caused the near extinction of native clams in Lake St. Clair and in the western basin of Lake Erie. The U.S. Fish and Wildlife Service estimates the economic impact caused by the zebra mussel at $5 billion over the next 10 years to U.S. and Canadian industries in the Great Lakes. The European ruffe is already the most numerous species in some areas of Lake Superior and is estimated to have the potential to cause devastating impacts on yellow perch and walleye fisheries. Exotic water fleas disrupt sportfishing by clinging to fishing lines and clogging fishing poles and reels.

On average, at least one new non-native organism is introduced into the Great Lakes each year. The next introduction could have even more devastating effects than have been observed with the present exotic species. Because of this severe threat to Lake Erie's aquatic ecosystem, including its commercial and recreational fisheries, from any new introductions of exotic organisms by ballast exchange, the Lake Erie Committee encourages and supports efforts to totally control all biological components of ballast within the Great Lakes Basin.

Adopted:
Annual Lake Erie Committee Meeting
March 29-30, 2000
Niagara-on-the-Lake, ON

LAKE ERIE COMMITTEE

POSITION STATEMENT

On

LaMP Rehabilitation of Nearshore Habitat and Lower Tributaries

Lake Erie Committee Endorses Lake Management Plan (LaMP 2002) Initiative under the Great Lakes Water Quality Agreement

The Lake Erie Committee believes that healthy fish communities are indicative of a healthy ecosystem;

- The governments of Canada and the USA, through the Great Lakes Water Quality Agreement, have directed the development of a Lakewide Management Plan for Lake Erie (LaMP);
- Ecosystem rehabilitation is a key objective of the LaMP;
- The LEC recognizes that degraded fish communities in near-shore waters and tributaries indicate environmental degradation and the need for rehabilitation;
- The Lake Erie Committee wants its interest groups to be aware of the LaMP 2002 initiative;
- The Lake Erie Committee supports the LaMP 2002 initiative for rehabilitation.

Adopted:
Annual Lake Erie Committee Meeting
March 27-28, 2002
Buffalo, NY

LAKE ERIE COMMITTEE

POSITION STATEMENT

On

Changing water level effects on Lake Erie and the Lake St. Clair Ecosystems

The Lake Erie Committee of the Great Lakes Fishery Commission understands that fluctuating water levels and the subsequent shifting of the littoral zone are important to the structure, function, and productivity of aquatic systems.

The Lake Erie Committee recognizes that:

a) a healthy fish community can be best achieved through strategies that include restoration of important coastal near-shore and tributary aquatic habitats (Fish Community Goals and Objectives for Lake Erie, 2003);
b) Lake Erie water levels have historically fluctuated over a 2-meter range and the US Army Corps of Engineers has established the Ordinary High Water (OHW) elevation for Lake Erie at 174.8 m (IGLD 1985);
c) associated with changing lake levels is a moving Aquatic Terrestrial Transition Zone (ATTZ) which needs to fluctuate freely in natural form;
d) shoreline modifications have degraded near-shore fish habitat, reducing the ability of Lake Erie to support healthy fish communities and that more than 40% of Lake Erie's fish species are classified as wetland dependent or facultative wetland dependent species;
e) given the low topographic relief associated with Lakes Erie and St. Clair, and the St. Clair, Detroit, and Niagara River systems, significant shoreline areas typically cover and uncover with decadal changes in water level;
f) currently, more than 90% of the southern shoreline of the western basin is hydro-modified and extensively armored, with very little near-shore aquatic vegetation or "shallow-water" habitat (<0.5 m). As the shoreline recedes from this armoring, there is increased potential for re-establishment of near-shore emergent and submerged vegetation and restoration of natural near-shore and coastal processes and connectivity;
g) there is the potential for Lake Erie water levels to change substantially over the next decade associated with natural lake level fluctuations, and the potential for significant declines in lake level associated with global climate change may create a new shoreline.

Given the potential gains associated with a newly exposed, and eventually re-vegetated, shoreline, and the impacts this will have in regards to restoration of fish community stability, and restoration of natural nearshore and coastal processes and associated ecosystem function, where practical, the Lake Erie Committee supports the free migration of the shoreline below the Ordinary High Water elevation which will allow for restoration of the fish communities associated with the Aquatic Terrestrial Transition Zone.

The Lake Erie Committee strongly encourages all resource agencies with management responsibilities on Lake Erie to commit resources to 1) re-establish natural vegetated shoreline within the range of decadal changes in Lake Erie water levels in balance with other coastal needs, 2) protect the right of the public trust, state, federal and provincial management agencies to actively manage these areas for native fish community restoration, and 3) promote research to help understand the significance of the Aquatic Terrestrial Transition Zone in maintaining healthy fish communities in Lakes Erie and St. Clair and connecting waters.

Adopted:
Annual Lake Erie Committee Meeting
March 30-31, 2005
Niagara Falls, Ontario