Report of the

LAKE ERIE
HABITAT TASK GROUP

Big Creek Marsh - Long Point Wetland Complex

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Presented to:

STANDING TECHNICAL COMMITTEE
LAKE ERIE COMMITTEE
GREAT LAKES FISHERY COMMISSION

Introduction

The Standing Technical Committee of the Lake Erie Committee (LEC) struck the Habitat Task Group (HTG) on March 1999. A previous committee composed primarily of founding members of the HTG presented draft Environmental Objectives to the LEC at the 1999 annual meeting. The primary focus of the HTG during its first year of existence was to further the development of the Lake Erie Environmental Objectives.

Specifically, the Charges to the HTG from the Standing Technical Committee for the period March 1999 to March 2000 were to:

1. Develop Terms-of-Reference for the newly established Habitat Task Group

2. Refine and quantify the draft LEC Environmental Objectives

3. Identify critical information needs to measure progress toward achievement of environmental objectives

4. Provide input to HAB to finalize the Great Lakes Habitat Declaration

5. Identify the priority areas for habitat rehabilitation efforts based on existing information

This report will respond to the above charges, and recommend charges to the HTG in 2000/2001.

Terms of Reference (Charge #1)

Preparation of Terms of Reference provided valuable assistance to the LEC Environmental Objectives Sub-Committee (EOSC) in the development of draft Environmental Objectives in 1998-99. It was felt that development of Terms of Reference for the HTG would provide similar guidance to the HTG in dealing with its charges.

The HTG planned to use the same format/headings utilized for the Environmental Objectives Terms of Reference. They are as follows:

1. Background
2. Purpose
3. Products
4. Guiding Principles
5. Accountability & Roles
6. Development Procedure
7. Schedule
8. Scope
9. Funding & Staffing Requirements

10. Integration
11. Implementation

Documentation of a procedure for the development of the Environmental Objectives (heading 6) proved to be the most useful aspect of the Terms of Reference to the EOSC. When attempting to apply the above format to the development of Terms of Reference for the HTG, we found most of the headings to be relatively straightforward. The major challenge came in attempting to identify and describe an approach that would allow the HTG to refine and quantify the draft Environmental Objectives. This problem plagued the HTG through most of the year. It was not until late in its term of mandate that the HTG was able to identify an approach to refinement of Environmental Objective that appears to show promise. Although this breakthrough in dealing with refinement of Environmental Objectives has the endorsement of HTG members, it came too late in the 1999/2000 mandate to incorporate into a Terms of Reference. The development approach, if endorsed by the STC, will be incorporated into a Terms of Reference during the 2000-2001 term of mandate.

The real value in developing a Terms of Reference is not so much in the end product, but in the knowledge gained in the development process. The HTG has identified an approach to the development of refined Environmental Objectives that is based on the physical processes that drive the system. We feel confident that the approach is practical and based on sound science, but it still needs to be validated through literature references and peer review.

Refinement and Quantification of the draft Environmental Objectives (Charge #2)

Background

The Joint Strategic Plan for Management of Great Lakes Fisheries (SGLFMP) directed Lake Committees to develop Fish Community Goals and Objectives (FCGO) for each lake, to identify environmental issues that may impede achievement of FCGOs, and to develop Environmental Objectives (EO) that would complement and facilitate the achievement of FCGOs.

Development of the Lake Erie FCGOs by the LEC was nearing an end by September 1997 (see Appendix A). At that time, the EOSC (a sub-committee of the LEC) was charged with the task of developing and quantifying EOs for Lake Erie that would complement these emerging FCGOs.

The EOSC used an approached that involved developing "Implied" Environmental Objectives through critical evaluation of each Fish Community Objective (Halyk *et al.* 1999). FCOs were grouped into four “modules” with linkages to physical processes (structuring forces on habitat) operating among them noted (Figure 1). A suite of environmental issues sifted out of this process that were either unique or common to

three of these modules (Trophic/Food-web Objectives, Bio-diversity Objectives, and Habitat Objectives). These issues involved:

- Cumulative incremental losses of habitat
- Hydrological functions in rivers and their attendant estuaries
- Fish access to reproductive habitats in rivers and coastal wetlands
- Hydrological processes along shorelines
- Oxygen and transparency conditions
- Fish community/food-web structure and interactions
- Contaminants

Eleven draft Implied EOs were crafted to address this suite of environmental issues. Target environmental conditions, end points, and information needs were addressed for each draft EO, albeit in a somewhat cursory fashion given the enormity of charge.

The summarized first iteration draft Implied Environmental Objectives that were arrived at by this process are:

1. Fish Habitat Protection
Reverse cumulative incremental loss and degradation of fish habitat required by Lake Erie fishes.

2. Tributaries and Estuaries
Restore natural hydrological functions in Lake Erie tributaries and estuaries.

3. Fish Access
Improve access to fish spawning and nursery habitat in rivers and coastal wetlands.

4. Shoreline Processes
Restore natural hydrological processes along the Lake Erie shoreline.

5. Submerged Macrophytes
Restore submerged macrophyte communities in estuaries and embayments.

6. Dissolved Oxygen
Maintain dissolved oxygen conditions necessary to complete all life history stages of Lake Erie fishes and forage species.

7. Food Web Structure
Facilitate the shift from a transient food web dominated by exotic species to one dominated by native species.

8. Species Introductions
Prevent the unauthorized introduction and establishment of additional non-native biota into the Lake Erie basin.

9. Contaminants
Minimize uptake of contaminants by Lake Erie fishes.

10. Open Water Transparency
Re-establish open water transparency conditions suitable for walleye in the eastern and central basins.

11. Stock Rehabilitation and Restoration
Rehabilitate locally adapted stocks of walleye, yellow perch and lake whitefish. Restore (where feasible) locally adapted stocks of lake sturgeon and lake herring and other native species.

Response to the Draft Environmental Objectives

The draft EOs were presented to LEC agencies, other federal, state, and provincial agencies, stakeholders, and the general public during the March, 1999 LEC meeting with a request for critical review and feedback by August 31, 1999. Copies were subsequently circulated to interested parties for several months thereafter. Despite this widespread circulation and solicitation of comments, the HTG received comments from only one source - the Ontario Commercial Fisheries Association.

This lack of feedback (positive or negative) is difficult to assess. Lack of strong negative response could be interpreted to mean that the draft EOs are a step in the right direction. However, lack of strong positive response could just as easily mean that the draft EOs, as written, are so vague and superficial that they would fail to be effective or practical as habitat management tools.

Refining the Environmental Objectives

Despite lack of public and agency response, it was assumed by the HTG that the draft EOs require further refinement. A strategy was developed for completion of the task of developing the Environmental Objectives for Lake Erie by the HTG, with the assistance of HAB/BOTE. The 1999-2000 charges to the Task Group were commensurate with this strategy. The draft Environmental Objectives were reviewed within the Task Group. A 2^{nd} iteration draft of these objectives was developed from an ecosystem perspective based on the linkages already developed between the FCGO modules and physical processes that strongly influenced aquatic habitats.

The concept of physical controls and biological accommodation over broad temporal scales introduces the perspective of parallel evolutionary histories of changing environment and co-evolved aquatic communities as the principal structuring forces on the fish community (Figure 2). The 2nd iteration of the draft Environmental Objectives draws support from an outline of a philosophy that incorporates these concepts as it's organizing principal (see Appendix B).

Physical controls and structuring forces that are crucial to the rehabilitation of habitats and fisheries benefits implied in the FCGOs are also amiable to management actions. This exercise identified issues associated with connectivity; affecting flow regime, water quality, ecological interaction in rivers and along shorelines and the role of a locally adapted, co-evolved native fish community. Rehabilitation of structuring forces in

tributary ecosystems and littoral habitats are consistent with reestablishing fish communities and food web structures founded on native species. The suitability and utilization of ancestral habitats and the contribution of allochthonous and littoral export production of carbon and carbon products on which the native fish community was founded will improve with the re-establishment of these structuring forces.

There are five 2nd iteration draft Environmental Objectives. The 1st iteration draft Environmental Objectives for Food Web Structure, Species Introductions, and Stock Rehabilitation and Restoration, that promote a return to a more robust co-evolved native fish community, were combined under a single Fish Community and Food Web Structure Objective. Three draft Environmental Objectives were put aside as being redundant (Fish Habitat Protection) or more suggestive of end-point targets (Dissolved Oxygen, and Open Water Transparency). One new objective was crafted to address the issue of altering geologic physical controls on lake basin integrity. The 2nd iteration of the draft Environmental Objectives are stated in this manner:

Tributaries and Estuaries
Re-establish the beneficial structuring forces of natural flow regime and water exchanges, circulation, and flow along and between channels and associated floodplains.

Shoreline Processes

Re-establish the beneficial structuring forces of natural water exchanges, circulation, and flow between the lake and littoral habitats.

Contaminants
Minimize exposure to contaminants by Lake Erie fishes in tributary and lake habitats.

Fish Community and Food Web Structure (composite)
Rehabilitate locally adapted stocks of walleye, yellow perch, and lake whitefish. Restore (where feasible) locally adapted stocks of lake sturgeon and lake herring and other native species. Prevent the unauthorized introduction and establishment of additional non-native biota to facilitate the shift from a transient food web dominated by exotics to one dominated by native species.

Lake Basin Integrity (new)
Maintain the beneficial structuring forces of natural oscillations in the amplitude and timing of lake-level stands in the Lake Erie basin.

Quantifying the Environmental Objectives
Like the EOSC before it, the HTG has had difficulty grappling with the task of quantifying Environmental Objectives. The challenge is compounded by the fact that the Lake Erie FCGOs in their current form are not quantifiable. The FCGOs are currently being revised, but major changes related to quantification are not expected.

The HTG has only just recently settled on an approach to further develop and refine the draft Environmental Objectives. Before we can quantify Environmental Objectives, we need to validate our approach in developing them. We are not there yet.

If endorsed by the STC, the HTG will explore opportunities for identifying appropriate endpoint targets for the 2nd iteration Environmental Objectives. Some of these endpoint targets could be quantified.

Information Needs, Supporting Projects and Activities (Random Acts of Conservation Biology in the Lake Basin - Charges 3 & 5)

Several projects related to information needs and habitat rehabilitation are underway or are being proposed in the lake basin.

An ongoing project that is currently being funded by the Great Lakes Protection Fund deals with the extent and effects of flow alteration on the fish community, specifically flow regime and watershed fragmentation (connectivity) in Great Lakes Basin rivers. Various aspects of this multi-facetted project will contribute significantly to our understanding of structuring forces on habitats and fish community in tributaries (*Project Title: Flow Alteration in Great Lakes Basin Rivers: Extent and Effects, J. David Allan and colleagues).*

Another multi partner (OMNR, OMOEE, GRCA) submission to the Great Lakes Protection Fund will study water quality, habitat, and fish community interactions at several riverine/nearshore locations along the north shore of the eastern basin *(Project Title: Environmental Issues and the Restoration of River and Nearshore Habitats and Dependent Fish Stocks in Eastern Lake Erie, Phil Ryan and colleagues).* If funded, this project will:

- Characterize the food web, fish community, and environmental conditions in lower reaches of rivers (Grand, Otter Creek, Sandusk Creek, Nanticoke Creek, Big Creek), and nearshore lake habitats.
- Identify factors affecting suitability of habitat and reproduction of key species (walleye, yellow perch, northern pike) and develop classification of levels of effect for turbidity, suspended solids, temperature, substrate.
- Describe the ecology and production of the Grand River walleye stock.
- Describe the genetic structure of eastern Lake Erie percid stocks, and their contribution to the mixed basin population.

The Ontario Ministry of Natural Resources, New York State Department of Environmental Conservation, and the Ohio Department of Natural Resources are engaged in rehabilitation strategies for locally adapted stocks of fish in the Grand River, Cattaraugus Creek, and the Sandusky River watersheds respectively. These projects involve provision of fish passage around barriers, riparian habitat protection and

enhancement, stormwater and rural wastewater management, soil conservation, and investigation of the feasibility of dam removal.

The work of the LEC Forage Task Group (Jeff *Tyson - ODNR*) documenting the repeated organizational patterns of fish distributions from August interagency trawl data, is an important step in understanding tributary inflows and hydrology as structuring forces on habitats in the nearshore. We need to be more cognizant of the effects of physical hydrology on the suitability and utilization of habitats in both the rivers and the lake. For instance, the progression of the spring thermal bar is, likely, a strong structuring force on the aggregation and retention of larvae, particularly for early spring spawners. It may, in fact, help to define boundaries for critical or essential habitats for some species.

Ohio Department of Natural Resources is engaged in the assessment of the Metzger Marsh rehabilitation project. The marsh is a 680 acre coastal wetland that was formerly diked. Connectivity between the marsh and Lake Erie was reestablish in 1999. Hydrology and the response of the plant and animal communities are being monitored.

Opportunities to gather data or rehabilitate habitat often arise unexpectedly. Recently, for example, HTG members were informed of plans by NOAA to gather bathymetric data for the Detroit and St. Clair River. The HTG may be the appropriate body to act on behalf of LEC agency members to contact proponents of projects such as this one to determine if partnership opportunities exist for supplementary habitat data collection.

Provide Input to HAB to finalize the Great Lakes Habitat Declaration (Charge #4)

The Habitat Advisory Board of the GLFC presented a Draft Declaration for the Conservation and Rehabilitation of Aquatic Habitat in the Great Lakes at the annual meeting of the Lower Great Lakes Committees on March 1999. The Declaration documents and re-enforces agency commitments to habitat protection and rehabilitation and outlines a strategy for implementation. The HTG was charged with the task of providing HAB assistance in finalizing development of the declaration.

By November 1999, the Habitat Declaration was set aside in favor of a Habitat Model Program. This approach involves changing the structure of HAB to allow agency members of the Lake Committees to be more involved in habitat issues. The Habitat Model Program is still under development. As a result of this shift in focus by HAB, the charge of providing assistance in the development of a Habitat Declaration is no longer germane.

Recommendations for 2000-2001

The 1999/2000 charges to the HTG were ambitious, and HTG members had great difficulty in addressing them completely. This was partly due to the complex nature of the subject matter, but was also largely due to the limited amount of time that could be devoted to the charges by HTG members due to competing internal and LEC priorities. The HTG recommends that LEC agency managers allocate sufficient staff time to HTG members to allow them to complete their charges. The Terms of Reference, once completed, will identify staffing and resource requirements for the 2000-2001 mandate.

The most important accomplishment during the 1999-2000 tenure was the identification of a proposed approach to refinement of Environmental Objectives that is based on the physical processes that determine the quality and quantity of habitat available to the Lake Erie fish community. This approach has yet to be fully endorsed by STC or the LEC. The recommended priority for 2000-2001 will be to validate this approach through literature and peer review. Development of functional Environmental Objectives must be based on a foundation of sound science. The HTG recognizes that quantified Objectives and endpoints are desirable and will ultimately be required to evaluate progress. However, given the limited staff and resources available, we feel it would be more beneficial at this point to focus on validating the process we have identified for EO refinement. In doing so, we expect that valuable information related to habitat quantification, priority rehabilitation areas and techniques, endpoints, and information needs will be identified as a bi-product of this review. This critical information will be documented and reported in the next HTG annual report but not in response to any formal charge in 2000-2001.

Validation of the Environmental Objectives refinement approach will be done in the following manner:

1. A writing team of HTG members will document supporting or opposing evidence for the proposed approach in the scientific literature
2. The HTG will seek internal (LEC) reaction to the proposed approach via the STC and TG chairs
3. The HTG will solicit feedback from recognized experts (e.g. Mackey, Seelbach, Imhof) via a workshop format.

Item 2 might be obtained via a proposed STC meeting designed to help all task group members address problematic charges.

Recommended charges to the HTG in 2000-2001

The HTG recommends the following charges to the group in 2000-2001:

1. Complete Terms of Reference for the Habitat Task Group. The Terms of Reference must include a detailed description of the process to be adopted to finalize development of Environmental Objectives.

2. Obtain STC endorsement and expert validation on a process for development and refinement of Environmental Objectives for the Lake Erie Fish Community.

3. Document habitat related projects (e.g. critical information collection, habitat rehabilitation projects, habitat quantification, etc.) being conducted or proposed by LEC agency members and partners in the Lake Erie Basin

References:

Halyk, L.C., Davies, D., Einhouse, D., Haas, R., Kenyon, R. 1999. Lake Erie Draft Environmental Objectives. Environmental Objectives Sub-Committee Report; Lake Erie Committee, Great Lakes Fishery Commission.

Figure 1: Organization of Lake Erie Fish Community Objectives. Thickness and direction of arrows between groups indicates strength of linkages.

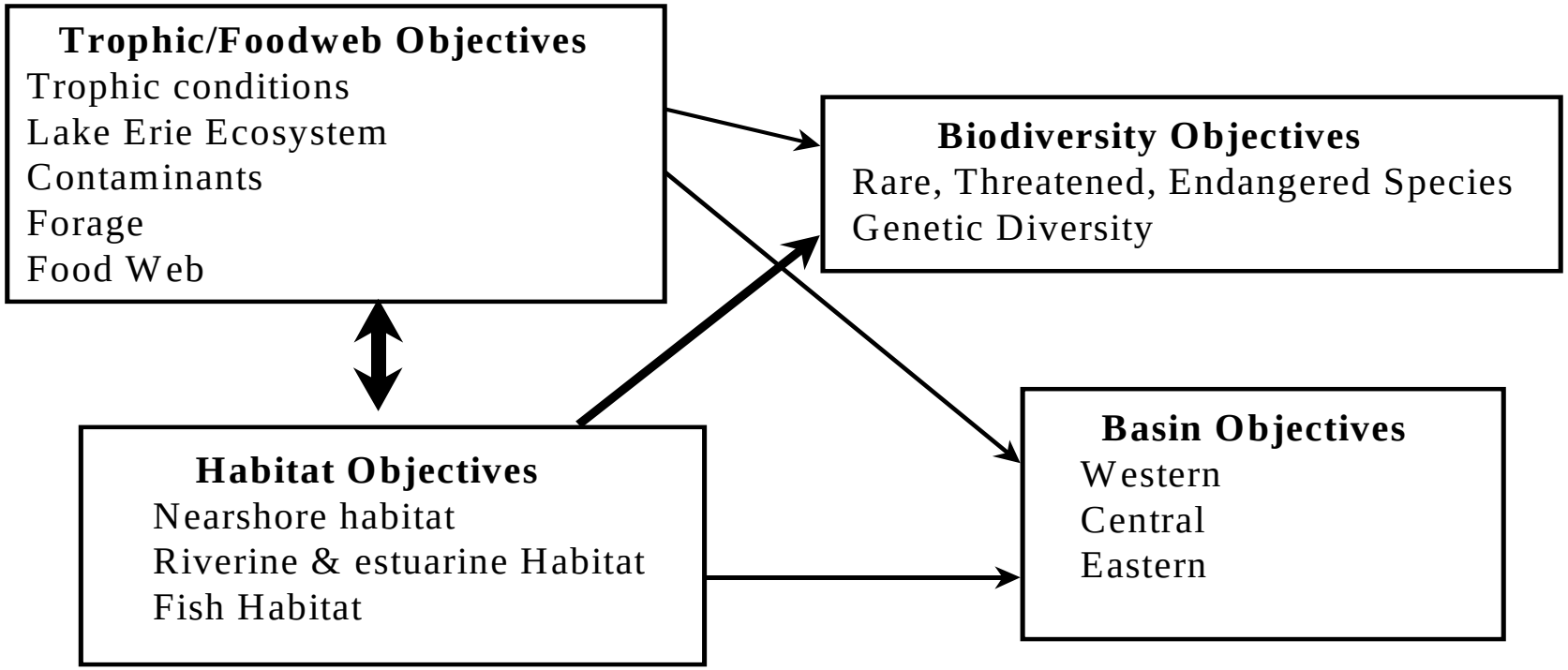
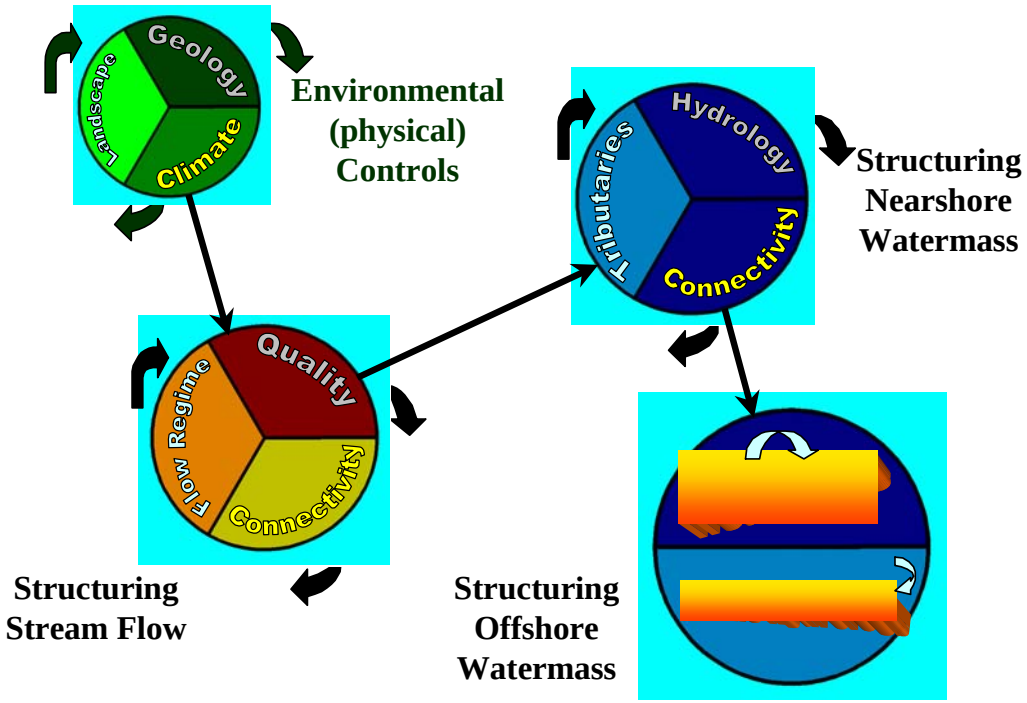


Figure 2: Physical controls and structuring forces on Lake Erie Basin aquatic habitats



Appendix A:
Lake Erie Fish Community Goal & Objectives

Lake Erie Environmental Objectives are intended to complement the Lake Erie Fish Community Goal and Objectives. A summary of the Lake Erie Goal and Objectives is presented below so that the reader can become familiar with the linkages between the Fish Community Objectives (FCOs) and the draft Environmental Objectives (EOs).

Lake Erie Goal

To secure a balanced, largely coolwater fish community, based upon a foundation of self-sustaining indigenous and naturalised species that occupies diverse habitats, provides valuable fisheries and reflects a healthy Lake Erie ecosystem. To manage walleye as a keystone species within a harmonic percid community on a sustainable yield basis for a broad distribution of benefits.

Fish Community Objectives

a) **Trophic Conditions**
Maintain a range of trophic conditions which accommodate a diverse fish community consisting largely of cool-water organisms [i.e. mesotrophic conditions (10-20 μg/l phosphorus) in the western basin, central basin and nearshore waters of the eastern basin of Lake Erie, following the natural gradient in productivity from west to east. Optimal summer transparencies for walleye should be in the range of 3-5 m in most areas of Lake Erie.]

b) **Lake Erie Ecosystem**
Manage the Lake Erie ecosystem to ensure high quality mesotrophic environments in the western basin, central basin and nearshore waters of the eastern basin, capable of supporting potential sustainable harvest of 50-60 million pounds of high valued fish species per year.

c) **Nearshore Habitat**
Manage nearshore habitat to support high quality fisheries for smallmouth bass, northern pike, muskellunge and walleye.

d) **Riverine and Estuarine Habitat**
Protect and restore self-sustaining, stream spawning stocks of walleye, white bass, lake sturgeon and rainbow trout. Restoration of stream spawning stocks of walleye would provide some added protection from wide fluctuations in year-class strengths.

e) **Western Basin**
Manage the western basin ecosystem to provide sustainable harvests of valued fish species, including walleye and yellow perch.

f) **Central Basin**
Manage the central basin ecosystem to provide sustainable harvests of valued fish species, including walleye, yellow perch, rainbow smelt and rainbow trout.

g) **Eastern Basin**
Manage the eastern basin ecosystem to provide sustainable harvests of valued fish species, including walleye, rainbow smelt, yellow perch, whitefish, lake trout, rainbow trout and other salmonids. Continue efforts to restore a self-sustaining population of lake trout to the modest levels of abundance observed historically that will serve as an integrating , terminal predator in the cold, profundal waters of the eastern basin.

h) **Contaminants**
Reduce contaminants in all fish species to levels that require no advisory for human consumption and no detrimental effect on fish-eating wildlife, fish behaviour/productivity and fish reproduction.

i) **Fish Habitat**
Protect, enhance and restore fish habitat throughout the watershed to ensure that the Lake Erie fish community is not degraded and that the fisheries it supports are not diminished.

j) **Genetic Diversity**
Maintain and promote genetic diversity by conserving locally adapted strains and by ensuring that if strains of fish are introduced, they are matched to the environments they are to inhabit. The ecological or genetic impacts of proposed new strains on native strains or populations will be considered by the LEC members prior to their introduction into Lake Erie.

k) **Rare, Threatened and Endangered Species**
Manage rare, threatened and endangered fish species (i.e. lake sturgeon, lake herring) in Lake Erie by reducing exploitation and protecting habitat to ensure that no more species become extinct.

l) **Forage**
Manage a diverse base of forage species to maintain abundance levels necessary to sustain use by predators with the fish community, and to sustain human use (i.e. exploitation of rainbow smelt, harvest of bait fish).

m) **Food Web Structure**
Manage the food web structure of Lake Erie to optimise production of high valued fish species. Recognise the importance of *Diporeia* and *Hexagenia* as key species of the food web and important indicators of habitat suitability.

Appendix B:
Guiding principles and management implications for ecological rehabilitation of aquatic habitats and fisheries benefits from the Lake Erie basin.

Physical controls on ecosystems result from environmental constraints imposed by the dynamic interactions of geology, climate, and landscape over a broad spectrum of temporal scales.

Geology

- Imposes profound physical controls on the lake basin that evolve over immense temporal scales. For example:
    - Inlet elevation changed approximately 5300 years ago, allowing the upper lakes drainage inflow to the Lake Erie basin. Lake-level rose 10 meters in a flood of biblical proportions.

- This event was a re-set point in the evolutionary history of the lake basin. The change in the lake level stand profoundly altered the morphology, geometry, and hydrology of lake basin aquatic habitats.

- The historic "native" fish community was an artifact of the structuring forces introduced by the change in geological physical controls and biological accommodation.

Climate

- Natural climate oscillations such as the Pacific Decadal Oscillation alternating states of La Nina and El Nino and the Neo Atlantic (a.k.a. Little Climate Optimum 800-1250 AD) followed by the Neo-boreal Episode (a.k.a. Little Ice Age 1430-1850 AD) of longer duration impose structuring forces of re-occurring alternating temperature and precipitation (cold/wet, warm/dry) regimes.

- Precipitation regimes on decadal or longer temporal scales act on lake level stands, affecting shoreline and estuary land margin habitats.

- The demand for water is growing worldwide and is an environmental issue potentially affecting decisions on the regulation, diversion, or harvesting Great Lakes water, which is an environmental issue that did not emerge in the first iteration of the draft Environmental Objectives.

- This issue raises the specter of altering lake basin integrity with respect to natural interactions of geological physical controls on climate regime, potentially affecting the amplitude or timing of natural and beneficial changes in lake level stands.

- Temperature regime effects are particularly constraining in the lake basin, which lies within the transition zone of the Canadian and Carolinian Biotic Provinces.

- Temperature regimes do affect fish community/food web interactions that are presently founded on a transient food web dominated by exotic species.

Landscape

- Were co-evolved mosaic plant communities founded on biological accommodation of physical controls imposed by environment-until 1492 AD.

- Unlike native American societies, Europeans were no longer constrained by their environment, having developed the capacity to significantly alter landscape.

- Change in landscape condition, tied to population growth in the lake basin, has been directional and will intensify.

- Cultural effects on landscape condition are amiable to management practices

Tributaries

- Rivers, because of their intimate contact with landscapes and people, are directly and immediately affected by landscape condition.

- Landscape condition affects the structuring forces of quantity (flow regime), quality, and connectivity of stream flow in river ecosystems.

- It all boils down to issues of connectivity!

- Natural flow regimes (the magnitude, timing, duration, frequency, and rates of change of water movements [and energy] within a watershed) evolved on the connectivity of water exchanges between headwater tributaries and their drainage sources (runoff, throughflow, and groundwater flows).

- Ecological interactions (spatial and temporal dependency) evolved on the connectivity of water exchanges between the channel and associated floodplains and along the channel linear axis under natural flow regimes. Ecological interactions responsive to connectivity would include:
    - Access to spawning sites, larval retention productivity centers, and refugiums.
    - Transit time and routing of larvae

- Export production from floodplains and wetlands (food supply)
- Processes associated with flow regime (energy), sediment dynamics, and connectivity regulate crucial aspects of structural habitat and water quality.
- Structure (substrate, energy)
- Substrate
- Grain size (availability, distribution)
- Porosity, Permeability
- Thickness
- Stability
- Energy (hydraulics)
- Depth
- Flow velocities
- Shear stress and turbulence
- Water quality (water mass, energy, connectivity)
- Suspended sediment concentrations and turbidity
- Temperature

- Water quality characteristics associated with cultural loading are strongly influenced by the connectivity of water exchanges between the channel and the assimilation capacity of associated floodplains.

Nearshore

- Tributary water mass inflows, lake hydrology, and shoreline landscape condition (connectivity) are structuring forces on nearshore environments.

- Nearshore environments are strongly linked to tributary water mass characteristics.
    - Temperature
    - Dissolved and suspended sediment concentrations
    - Turbidity
    - Chemistry, Oxygen
    - Allochthonous food supply

- The behavior of tributary water masses in the nearshore is controlled by lake hydrology and shoreline landscape.

- Variation in lake hydrology is attributed to climatic physical controls with strong seasonal components in most years.

- Aspects of lake hydrological which contribute to repeated organizational patterns of flow, current, and circulation in the nearshore include:
    - Flow associated with lake basin discharge
    - Lake level changes

- Wind tides
- Seiche
- Littoral current
- Spring thermal bar

- Shoreline landscape (connectivity) controls interactions with hydrology (flow, current, and circulation patterns) in nearshore littoral habitats.

- Connectivity, here, refers to the exchange of water between the lake and associated coastal floodplains and along the nearshore littoral zone.
    - Affected littoral habitats/functions include:
    - Larval retention and productivity centers
    - Littoral export production to the food supply
    - Fish access to coastal wetlands

Offshore

- Nearshore water masses and lake hydrology are structuring forces on offshore water mass environments, setting up gradients predominately along a west to east axis.

- Offshore habitats are strongly linked to nearshore larval and juvenile productivity centers.

- Nearly all Lake Erie fish species utilize nearshore habitats during their early life history stages.

- Historically, lake herring filled an important niche as an energy conduit during repeated migrations and aggregations.