SOLEC 2000

Biodiversity Investment Areas

Integration

Background Paper

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1.0 Introduction

The Great Lakes basin ecosystem is one of the most productive economic systems in the world. Yet its economic health is fully dependent on natural resources and fragile ecological relationships. The lakes and coastal wetlands are rich in aquatic life, and the shoreline area has an array of specialized natural features such as sand beaches and dunes, lakeplain prairies, oak savannas, and more than 30,000 islands. More than 130 globally rare communities and species are found here.

This image of the landscape as a colorful backdrop for a variety of life – biodiversity – is at the center of the region's character. The integrity of the ecosystem is dependent on the health of the full spectrum of life forms and supporting habitat. This paper is an initial attempt to integrate the best of highly diverse coastal aquatic, wetland, and terrestrial biodiversity resources into a coherent set of priority areas known as Biodiversity Investment Areas (BIAs). It is hoped that Biodiversity Investment Areas will provide opportunities for positive new efforts to protect and restore the region's resources.

1.1 Definition

Shoreline Biodiversity Investment Areas are broad coastal areas, including associated landscapes and shallow waters, that contain clusters of exceptional biodiversity values. BIAs highlight sections of Great Lakes shoreline that sustain rare and diverse plant, fish and animal communities, contain landscape features of special quality, and/or are especially productive. Protecting the ecological richness of these areas is an essential facet of maintaining the integrity of the Great Lakes basin ecosystem.

1.2 Three Approaches to the BIA Concept

The Biodiversity Investment Area concept was introduced in the 1996 State of the Lakes Ecosystem Conference (SOLEC) background paper Land by the Lakes, Nearshore Terrestrial Ecosystems (Reid and Holland 1996) as a construct to assess the health of combinations of special lakeshore communities such as sand dunes and bedrock shores. Land by the Lakes detailed the status of nearshore terrestrial ecosystems, the stressors affecting its health, and the stewardship activities counteracting the stressors. The conclusion was that nearshore terrestrial ecosystems are degrading throughout the Great Lakes.

This conclusion served to focus attention on areas of unusual biological significance and in need of protection from human impacts. The phrase "Biodiversity Investment Areas" was coined as a positive reminder that actions to protect biodiversity are an investment in the future of the region.

Nineteen nearshore terrestrial biodiversity investment areas were identified for SOLEC 1996. The identification of these areas did not mean there are no other significant areas of biodiversity in the basin. Numerous other high quality, but smaller, areas were known to exist. However, nearshore terrestrial BIAs presented key opportunities to protect the quality of large areas that would preserve ecological integrity and, ultimately, help protect the health of the Great Lakes.

To identify BIAs for the Great Lakes nearshore terrestrial areas, places with exceptional biodiversity values were chosen, including:

- Multiple or outstanding examples of Great Lakes shoreline special communities. Twelve kinds of special shoreline communities were identified in the SOLEC 1996 Land by the Lakes paper. Examples of special shoreline communities are sand dunes, bedrock shore, and lakeplain prairies.

- Concentrations of species of special interest such as Pitchers thistle, piping plover, and the Karner blue butterfly.

- Excellent examples of representation of coastal landforms or typical vegetation and wildlife communities, particularly those in excellent condition or of unusually high quality.

- Exceptional levels of natural habitat and species diversity. The lakeplain prairies of Walpole Island, for example, are exceptionally species diverse.

- High levels of ecological connectivity, both along the shoreline and to inland or offshore natural features. Wolf packs, for example, travel along a thin corridor to and from the Bad River Watershed and the western Upper Peninsula of Michigan.

At SOLEC 1998, an expanded look at nearshore terrestrial BIAs further characterized their features and values, threats to biodiversity, protection measures in place, and key protection and restoration needs. An attempt was made to assess their ecological health. The hope was that attention to these areas would result in an increase in on-the-ground protection and restoration activities.

In addition to an expanded look at nearshore terrestrial BIAs at SOLEC 1998, coastal wetlands and nearshore aquatic papers explored the BIA concept. These approaches differed considerably.

The Coastal Wetland Biodiversity Investment Area paper set an objective of identifying areas that contain high quality faunal habitat. This report stopped short of labeling areas as BIAs, but mapped coastal reaches (eco-reaches) that support ecologically distinctive wetland types. The need to create a GIS-based inventory of all coastal wetlands and to develop a consistent terminology for classifying and describing coastal wetland types was identified.

The Aquatic Biodiversity Investment Area paper defined aquatic BIAs as specific locations or areas within a larger ecosystem that are especially productive, support exceptionally high biodiversity and/or endemism, and contribute significantly to the integrity of the whole ecosystem. This definition encompasses consideration of centers of high levels of natural, self-sustaining productivity and ecological integrity of ecosystems as envisaged in the successive versions of the Canada-United States Great Lakes Water Quality Agreement. A survey of Great Lakes scientists elicited preliminary recommendations for designating areas as Aquatic BIAs.

1.3 Purpose and Justification for the Designation

Designation of Biodiversity Investment Areas focuses attention on places of importance in the Great Lakes nearshore zone. It highlights the good news that the Great Lakes coastline still retains large sections with high natural values. It is a mechanism for protecting significant sites, for encouraging ecological restoration where some degradation has occurred, for understanding and developing the science needed to measure change, and for demonstrating linkages between the productivity of a full range of species and the functions of particular landscapes. Incorporating the concept of BIAs into the cultural conscientiousness of the region encourages engagement by citizens as well as measures to protect the integrity of the basin.

The BIA concept is a vision of the healthy areas of the Great Lakes basin which contrasts with our images of polluted landscapes. BIAs are rich with examples of healthy plants and animals living in functioning ecosystems. They are historic and ecological repositories for future exploration. They are outdoor classrooms, complete with learning adventures.

The language of the 1978 Great Lakes Water Quality Agreement provides a compelling reason for designating areas of the Great Lakes basin as BIAs. Stating that the governments of Canada and the United States have a responsibility to "Restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem", the Agreement outlines objectives with regard to the beneficial uses and impaired uses of coastal areas of the Great Lakes. In its latest report on Great Lakes Water Quality, the International Joint Commission recommended that “Governments should proceed with implementation of the SOLEC work on Biodiversity Investment Areas, emphasizing the preservation and rehabilitation of wetlands” (IJC 2000).

Internationally, the Convention on Biological Diversity, an agreement to protect the diversity of plant and animal life throughout the planet, signifies recognition of the loss of biodiversity as a global problem. BIA designation is a regional attempt to participate in this worldwide effort to stem biodiversity losses.

Protecting the habitats of areas of known biological diversity is a basic strategy for preserving biodiversity. These places serve as source areas for populations of rare and threatened species. Areas that are biologically diverse and functioning well also serve as benchmarks for restoration efforts where degradation has occurred. Basinwide indicators developed for SOLEC 1998 and reported on for SOLEC 2000 are dependent on baseline information provided by relatively intact systems as exemplified in the BIAs.

Finally, the designation of areas as Biodiversity Investment Areas serves to heighten civic environmentalism, environmental action based on a shared social vision. Unless communities around the Great Lakes basin recognize the importance of biodiversity as integral to culture as well as to the economy, protection efforts will go unrecognized or be deemed unnecessary.

1.4 Contents of the BIA Integration Paper

The following steps to refine the criteria for BIA designation and to integrate previous efforts were proposed at SOLEC 1998:

- The process of identifying potential BIAs needs a general overarching classification system in which the different classes of BIAs can be interlocked and nested. This is essential in order for the Parties, their non-governmental partners, and the International Joint Commission to set priorities for securement.

- The three BIA approaches need to be merged into a single set of coastal BIAs.

- Aquatic BIAs identified at SOLEC 1998 need further refinement with input from additional resource managers.

- A consistent wetlands classification system is needed in order to understand their complexity, measure their health and incorporate them into the BIA scheme.

- All BIAs are in need of locally-based assessments to identify the most important biological communities and species, physiographic features and sites, key processes supporting biodiversity, key stressors affecting biodiversity, and conditions needed to protect ecosystem integrity.

- Ways to implement the BIA concept through actions by the IJC, Lakewide Management Planning, Federal, State/Provincial and local government bodies need to be examined.

- Prior to SOLEC 2000, a workshop for resource managers and interested parties to work through the above recommendations will validate and lend credence to the BIA concept.

This paper is a beginning response to the above directions. It integrates the Biodiversity Investment Area concepts presented at SOLEC 1998. Section 2.0 outlines the principles used to identify an integrated set of BIAs, as well as the criteria and guidelines for their application. Section 3.0 evaluates the criteria for an integrated set of BIAs, using a series of 10 basin-wide databases. Section 4.0 contains the new map of Biodiversity Investment Areas. Section 5.0 presents opportunities for protection and restoration within the BIAs. Finally, Appendix A details three case studies that show how research is helping to define actions and tools to protect and restore key living resources, systems integrity and productivity in high-quality areas from the upland to the lakes.

2.0 Identifying an Integrated Set of Biodiversity Investment Areas

One of the key directions from the review of nearshore terrestrial, wetlands, and aquatic BIAs at SOLEC 98 was the desire to bring together the three approaches into a single integrated set of Biodiversity Investment Areas. This chapter outlines several principles that provide a basis for integration; the process used to identify integrated BIAs, and a series of integrated BIA criteria with guidelines for their application.

Principles for Integration:

1. **Focus on the nearshore first:**
For SOLEC 2000, BIA integration will focus on the nearshore area only; other components of the Great Lakes basin ecosystem should be addressed in subsequent years. Nearshore includes coastal wetlands, coastal waters extending offshore to the point where the thermocline typically intersects with the lake bed in late summer, and nearshore terrestrial areas directly affected by the lake (generally within 1 km), including peninsulas and islands.

2. **Base BIAs on clusters of values:**
BIAs are intended to portray landscapes of exceptional quality at the regional level. The identification of BIAs is based on clusters of values in the same geographic vicinity, rather than isolated individual sites of significance. Those clusters may be all one type of ecological value (e.g. all coastal marshes), or they may include a mix of terrestrial, wetland and aquatic values. The density of those values on the landscape are a key factor.

3. **Values are measured relative to other areas:**
In general, the criteria are intended to recognize ecological values relative to other landscapes across the Great Lakes basin (e.g. one of the best examples of coastal dunes on the Great Lakes), or relative to other sections of the same lake (e.g. the most productive aquatic nursery area on that lake).

4. **BIAs can include areas with potential for restoration:**
Where possible, values will be based on the historical potential at that location (e.g. high fish or benthic invertebrate abundance at the time of European settlement) if the basic physical environment has not been altered to such an extent that restoration is unlikely to ever occur. For example, the former extensive marshlands at Ashbridge's Bay in the City of Toronto have been completely filled and converted to industrial lands, and offer very limited potential for restoration; on the other hand, the prairie and dune communities within the Chicago Wilderness area, while seriously fragmented, still retain remnants of many community types and species not represented elsewhere along the nearshore, and offer good potential for further restoration.

Process for Identifying Integrated BIAs:

The process for identifying an integrated set of nearshore BIAs was based initially on four previously published works:

a. A description of 20 proposed BIAs for nearshore terrestrial ecosystems provided for SOLEC 98 (Reid, Rodriguez and Mysz 1999);

b. A parallel paper prepared for SOLEC 98 on coastal wetland BIAs (Chow-Fraser and Albert 1998), which maps coastal eco-reaches and wetlands, but does not propose specific BIAs;

c. A background paper on BIAs for aquatic ecosystems also drafted for SOLEC 98 (Koonce, Minns and Morrison 1998), which presents a conceptual approach and the results of a survey of fisheries scientists, but does not propose specific BIAs; and

d. An aquatic community classification framework developed by The Nature Conservancy (Higgins et al. 1998), which includes a classification of Great Lakes nearshore habitats and an initial quality analysis for these areas.

A five-step process was used to identify and evaluate potential integrated BIAs:

1. **Selection of shoreline units:**
   A series of 70 shoreline units were selected as a basis for analysis. The coastal eco-reaches identified by the 1998 Coastal Wetlands BIAs paper were used as a starting point for integration. Some of those units were further sub-divided to correspond to boundaries on the nearshore terrestrial BIAs, to incorporated mapping of nearshore zones on the U.S. side by Higgins et al. (1998), and to account for other major changes in nearshore character (See Figure 1).

2. **Develop evaluation criteria and application guidelines:**
   In order to address fairly all three former BIA types along the nearshore (wetlands, terrestrial, aquatic), three broad evaluation criteria are proposed, relating to species/communities of special interest, diversity, and productivity and integrity. Within each criterion, a series of contributing values are identified, along with potential data sets or indicators that could assist in a relative evaluation of each (See Table 1). Application guidelines for the data sets relating to each criterion were also developed, so that they could be applied to each BIA under consideration and summarized with a ranking of A-D, with A-ranks representing the highest values for that criterion, and D-ranks the lowest.

3. **Identify available data sets:**
   A total of ten data sets were identified which could be used to apply the evaluation criteria to the entire Great Lakes shoreline. Most of these data sets are in digital format, and in most cases, they are available in directly comparable formats for both the Canadian

and U.S. sides of the basin. Data sets on rare species, coastal wetlands and representative high-quality areas are not directly comparable between the two countries, but the most similar data available were used. Data was summarized for each of the 70 shoreline units, and adjusted in relation to the shoreline length of each unit where necessary to provide valid comparisons.

4. **Complete first-cut mapping:**
   Based on this analysis, an evaluation ranking was assigned for each of the three criteria for each shoreline unit. Units were then assigned to tiers based on their composite rankings for all three criteria, i.e. with AAA at the top, then AAB, AAC, ABB, and so on. Shoreline units with the highest overall rankings were highlighted as potential Biodiversity Investment Areas.

5. **Present mapping for review by SOLEC 2000:**
   The revised mapping, along with the analysis and data supporting it, are provided in this background report for review and improvement at the SOLEC 2000 conference.

[insert Figure 1: Shoreline Units - file noname shore units]

Table 1: Integrated BIA Criteria	
Contributing values	**Potential data sets**
Criterion 1: Species or Communities of Special Interest	
a. Species or communities that are rare or endangered	Federal, State and provincial natural heritage databanks
b. Endemic species	Federal, State and provincial natural heritage databanks
c. High-quality examples of representative habitats, special communities, or landforms	ANSIs in Ontario; theme studies such as Michigan Bedrock Shores, International Alvar study; TNC ecoregional priority sites; coastal wetlands; Lake Superior Important Habitats
d. Fish or wildlife concentration areas	Colonial bird surveys, Important Bird Areas, waterfowl use surveys, anadramous fish migration routes
Criterion 2: Diversity of habitats, communities and species	
a. Landform diversity	Topographic or bathymetric diversity; soil type or bottom sediment diversity; shoreline type diversity
b. Shoreline complexity	Complexity of shoreline shape; offshore islands and shoals
c. Diversity of community types	Vegetation communities; fish and invertebrate communities
d. Diversity of species	Species lists for sites within the potential BIA and/or regional species lists; breeding bird atlas data; fish atlas data
Criterion 3: Productivity and Integrity	
a. Physical potential for productivity	Intactness of landform structures to support abundance levels for fish, invertebrates, wildlife or vegetation comparable to historic levels
b. Importance to productivity or abundance of particular species or groups	Critical habitats for a life-stage of wide-ranging species that affect the integrity of large regions (e.g. spawning grounds for lake trout; waterfowl staging areas)
c. Intactness of ecological pathways and processes	Degree of impairment of historic pathways by species extirpations, toxins, trophic level imbalances, non-indigenous species, dams and barriers; degree of intactness of natural disturbances
d. Size and connectivity	Extent of habitat patches compared to historic conditions; degree of connectivity among habitats

3.0 Using Integrated BIA Criteria to Identify Priority Areas

This chapter describes how a series of 10 data sets, along with other information where available, was used to apply the three Integrated BIA criteria to each of the 70 shoreline units.

The length of shoreline within each shoreline unit was calculated using medium resolution vector shoreline data compiled by the United States Army Corps of Engineers (USACE) and Environment Canada (International Joint Commission 1993). These coverages and associated metadata are available at http://www.glerl.noaa.gov/data/char/. Lengths include island perimeters as well as mainland shoreline. All lengths were rounded to the nearest kilometer.

The approach used in this analysis is hierarchical. Information from individual data sets is analyzed to identify relatively high or low values for each shoreline unit. Then the complete set of information layers within each criterion are compiled, so that shoreline units with multiple values can be ranked from A to D. Finally, these rankings for each of the three criteria are brought together, so that those with high rankings for several criteria can be highlighted as potential Biodiversity Investment Areas.

3.1 Evaluating Criterion 1: Species or Communities of Special Interest

To paraphrase Aldo Leopold, "the first act of intelligent thinking is to save all the pieces". In the context of biodiversity conservation, this means that one of the first priorities is to protect the full range of biological communities, species, and genetic variability within the Great Lakes region. Communities or species which have become rare or threatened (and those which have always occurred sparsely) need particular attention to ensure they are not lost from the web of biodiversity. Others sites which may be particularly vulnerable to disruption, such as seasonal concentration areas for fish and wildlife, are also considered under this criterion, as well as high-quality examples of representative habitats.

Four primary data sets were analyzed to assist in assigning rankings to each of the 70 shoreline units for this criterion:

- Mapping of known occurrences along the shoreline of communities or species identified as rare, threatened, or endangered.
- Occurrence mapping of high-quality habitat areas formally identified for protection of representative or high-value natural communities.
- Occurrence mapping of coastal wetlands identified as having provincial or state-level significance.
- Distribution of Important Bird Areas formally identified within the nearshore area.

Each of these data sets and an explanation of how they were used is outlined below. Several other data sources could be used to further refine the application of this criterion in future, such as :

- Thematic studies of Great Lakes coastal features, such as dunes, alvars, or bedrock shores, which identify examples of exceptional quality.

- More detailed data on fish and wildlife concentration areas, such as colonial bird surveys, waterfowl use surveys, anadramous fish migration routes, or fish spawning or congregation areas.

- Mapping of occurrences of endemic species along the shoreline. Endemic species are those that occur only within the Great Lakes region, and could also be defined to include species which have more than 50% of their global range and/or have their best examples within the Great Lakes basin. A list of endemic species is available from the report entitled *The Conservation of Biological Diversity in the Great Lakes Ecosystem: Issues and Opportunities* (The Nature Conservancy Great Lakes Program 1994), which for coastal lands and waters, would include:

Lake Sturgeon	*Acipenser fulvescens*
Rugulose Grapefern	*Botrychium rugulosum*
Bluehearts	*Buchnera americana*
Handsome Sedge	*Carex formosa*
Piping Plover	*Charadrius melodus*
Hill's Thistle	*Cirsium hillii*
Pitcher's Thistle	*Cirsium pitcheri*
Ram's-head Lady's-slipper	*Cypripedium arietinum*
Lakeside Daisy	*Hymenoxys herbacea*
Dwarf Lake Iris	*Iris lacustris*
Karner Blue	*Lycaeides melissa samuelis*
Pugnose Shiner	*Notropis anogenus*
Eastern Prairie White-fringed Orchid	*Platanthera leucophaea*
Houghton's Goldenrod	*Solidago houghtonii*
Lake Huron Locust	*Trimerotropis huroniana*

Applying guidelines to the data sets:

Rare species and communities:

As part of an international program operated by The Nature Conservancy (TNC), biological communities and species have been assigned "global ranks", which represent their conservation status on a global scale. TNC's global ranks range from G1 for critically imperiled (very few occurrences anywhere in the world and highly threatened) to G5 for demonstrably secure (many occurrences worldwide and may of those in some sort of conservation management or ownership). State and provincial natural heritage databases track the known occurrences of rare or uncommon species and communities, and were consulted as the basis for this data set.

Information on G1 to G3 species and communities occurring within 1 km of the Great Lakes shoreline or in nearshore waters was compiled for each shoreline unit, with the number of occurrences shown in Table 2. Data on the U.S. side is considerably less accurate, since rare species/communities occurrences were mapped on a coarser scale within 7.5 minute quadrangles, which could not be matched definitively to individual shoreline units, and which extend further inland than 1 km. As well, there is concern that some areas may have been more intensively surveyed than others, and that high numbers of element occurrences could be due to a dominance of highly visible or easily identified species. Data on both sides of the border is weak for aquatic species.

Because of the differences between the Canadian and U.S. data, rarity rankings were based on comparisons within each country separately. Since the length of individual shoreline units varies widely, a unit of less than 100 km in length was considered to score High if it has more than 10 G1-G3 element occurrences in Canada, or more than 50 occurrences in the U.S. A rating of Moderate was assigned in units of less than 100 km if there were more than 5 occurrences in Canada, or 20 occurrences in the U.S. For all shoreline units longer than 100 km, a High score reflects more than 20 occurrences in Canada or 100 in the U.S., and a Moderate score more than 8 occurrences in Canada or 25 occurrences in the U.S.. These ratings for each shoreline unit are shown on Table 2 in the Rarity Rating column.

High-quality habitats:

On both sides of the international border, natural areas have been identified which provide the best available representation of the full spectrum of biodiversity.

The Nature Conservancy Great Lakes Program recently completed a planning process to identify important sites for conserving biodiversity within the U.S. portion of Great Lakes ecoregion (The Nature Conservancy, Great Lakes Program 2000). The Great Lakes Program worked with partners across the region to identify a collection of conservation sites that contain high quality examples of rare and representative habitats, species and communities; if these sites are fully protected, the full range of native biodiversity in the Great Lakes ecoregion will be conserved.

On the Canadian side, roughly equivalent high-quality representative natural areas have been derived from three sources. Provincially significant Areas of Natural and Scientific Interest (ANSIs) have been identified by the provincial Ministry of Natural Resources to represent both life science and earth science features. Second, Ontario Living Legacy (OLL) sites are a suite of new parks and conservation reserves that were approved in 1999 to protect high-quality natural areas, including many areas along the Great Lakes coast. Third, nearshore nature reserves owned by non-government conservation organizations were identified and considered.

For the Lake Superior shoreline, recent mapping of Important Habitats produced by the Lake Superior Binational Program (Collins and Sjerven 2000) was consulted for both sides of the border.

For each shoreline unit, the number of priority high-quality sites that occur within 1 km of the shoreline are listed in Table 2. In addition, the size of all sites within each shoreline unit is listed where known, or their extent along the nearshore zone is estimated as extensive, moderate, or limited. In order to take into account the varying shoreline lengths within each of the 70 units, each unit was rated according to the following guidelines:

For shoreline units under 100 km in length (12 units):
H - High: over 1500 ha or estimated as extensive
M - Moderate: over 300 ha or estimated as moderate extent

For shoreline units from 100-199 km long (24 units):
H- High: over 2000 ha or 10 sites or estimated as extensive
M - Moderate: over 500 ha or 5 sites or estimated as moderate extent

For shoreline units from 200-299 km long (11 units):
H - High: over 2500 ha or 10 sites or estimated as extensive
M - Moderate: over 1000 ha or 7 sites or estimated as moderate extent

For shoreline units from 300-499 km long (14 units):
H - High: over 5000 ha or 12 sites or estimated as extensive
M - Moderate: over 2000 ha or 7 sites or estimated as moderate extent

For shoreline units over 500 km long (9 units):
H - High: over 10,000 ha or 15 sites or estimated as extensive
M - Moderate: over 5000 ha or 10 sites or estimated as moderate extent

All other units are rated as Low, as shown in Table 2.

Coastal wetlands:

Coastal wetlands have been identified as habitats of special interest because of their significant role in the nearshore ecosystem for fish and wildlife communities (Maynard and Wilcox 1996; Chow-Fraser and Albert 1998). The number and total size of coastal wetlands within each shoreline unit was compiled from several sources:

- A *Coastal Wetlands Atlas* recently prepared by the Ontario Ministry of Natural Resources and Environment Canada (OMNR and Environment Canada, in press).
- A listing of coastal wetlands in the 1998 Coastal Wetlands BIA report (Chow-Fraser and Albert 1998).
- Descriptions of coastal wetlands occurrence and status from the 1996 SOLEC wetlands report (Maynard and Wilcox 1996).

Where numerical data was not available, the number and extent of coastal wetland habitats within a shoreline unit was estimated as extensive, moderate, or limited. The relationship of the wetlands information to the length of shoreline units was examined, but since this relationship was less clear than for other factors, a simplified stratification was used:

For all shoreline units less than 500 km in length:

- H - High: over 1000 ha or 11 sites
- M - Moderate: over 500 ha or 5 sites
- L - Low: less than 500 ha or 5 sites

For shoreline units more than 500 km in length:

- H - High: over 2000 ha or 20 sites
- M - Moderate: over 1000 ha or 10 sites
- L - Low: less than 1000 ha or 10 sites

In addition, several shoreline units were recognized as VH - Very High, with total wetland size of over 5000 ha.

Important Bird Areas:

Important Bird Areas (IBAs) are a program of BirdLife International, which is currently coordinated in the U.S. by National Audubon Society (and formerly by the American Bird Conservancy) and in Canada by Bird Studies Canada and Canadian Nature Federation. The IBA program uses four categories of criteria to identify sites of national, continental, or global significance for breeding and migrant birds. A three-year program to identify IBAs within the Great Lakes basin is near completion, and has identified 141 significant sites (Reid, in press). In addition, a study of key breeding sites for primary focus species plus stopover sites for migrant birds has recently been completed by The Nature Conservancy (Ewert 1999).

Sites along the Great Lakes shoreline identified through either of these processes have been tabulated in Table 2. As well as noting the number of IBAs within each shoreline unit, their total extent is estimated and noted as extensive (involving more than approximately 50% of the shoreline length); moderate (involving approximately 10-49% of the shoreline length), or limited (present but totaling less than 10% of the shoreline length).

Guidelines for ranking:

All five ratings were considered in ranking each shoreline unit from A (highest priority) to D (lowest). The following guidelines were used:

A-ranked: Any 3 High scores (including Extensive for Important Bird Areas and a maximum of one M-H score), or
1 Very High plus one other High score.

B-ranked: Any 2 High scores.

C-ranked: Any 1 High score, or any 3 Moderate scores.

D-ranked: All scores lower than above.

These summary rankings for Criterion 1 are shown in the final column of Table 2, and on Figure 2.

Table 2: Ranking of Shoreline Units based on Criterion 1

Shoreline Unit	Length of shoreline (km)	Rare Species/ Comm. (#)	Rarity Rating	High-Quality Areas (# - size-ha)	High-Quality Areas Rating	Coastal Wetlands (# - size-ha)	Coastal Wetlands Rating	Important Bird Areas (# - extent)	Criterion 1 (Special Interest) Ranking
OS 1	588	15	L	4 (121)	L	9 (2061)	H	1 (Ext)	**B**
OS 2	487	52	M	7 (2500)	M	6 (1475)	H	1 (Ext)	**B**
OS 3a	961	14	M	25 (6120)	H	37 (9019)	VH	3 (Mod)	**A**
OS 3b	303	36	M	4 (Ext)	H	5 (Mod)	M	1 (Ext)	**B**
OS 4a	253	12	M	5 (800)	L	10 (455)	M	3 (Lim)	**D**
OS 4b	144	1	L	14 (1026)	M-H	17 (657)	H	-	**C**
OS 4c	50	2	L	1 (2343)	H	3 (1112)	H	1 (Ext)	**A**
OS 5	136	2	L	3 (Lim)	L	1 (Lim)	L	-	**D**
OS 6	191	21	L	4 (Lim)	L	4 (Mod)	M	5 (Ext)	**C**
OS 7	42	25	M	1 (Ext)	H	3 (Mod)	M	1 (Ext)	**B**
E 1	166	11	M	4 (500)	M	4 (85)	L	1 (Ext)	**C**
E 2	161	9	L	6 (900)	M	9 (941)	M	2 (Lim)	**D**
E 3	117	15	M	2 (10500)	H	2 (13576)	VH	1 (Ext)	**A**
E4	222	15	M	8 (6521)	H	3 (1684)	H	1 (Lim)	**B**
E 5	105	28	H	6 (2600)	M-H	9 (1797)	H	2 (Mod)	**A**
E6a	427	210	H	9 (Mod)	M	18 (6000+)	VH	3 (Ext)	**A**
E6b	154	358	H	9 (660)	M-H	2 (130)	L	3 (Ext)	**A**
E 7a	48	4	L	1 (Lim)	L	Lim	L	-	**D**

Shoreline Unit	Length of shoreline (km)	Rare Species/ Comm. (#)	Rarity Rating	High-Quality Areas (# - size-ha)	High-Quality Areas Rating	Coastal Wetlands (# - size-ha)	Coastal Wetlands Rating	Important Bird Areas (# - extent)	Criterion 1 (Special Interest) Ranking
E7b	198	51	M	7 (Mod)	M	Lim	L	3 (Lim)	**D**
E7c	59	194	H	1 (Ext)	H	3 (162)	M-L	1 (Ext)	**A**
E 7d	166	175	H	5 (Lim)	L	Lim	L	1 (Lim)	**C**
SC 1	178	102	M-H	2 (200)	L	21 (1518)	H	2 (Ext)	**B**
SC 2	666	97	H	3 (650)	M	18 (16000+)	VH	3 (Mod)	**A**
SC 3	88	15	L	-	L	6 (96)	L	-	**D**
HG 1a	175	1	L	1 (Lim)	L	2 (Lim)	L	-	**D**
HG 1b	99	14	H	6 (1764)	H	2 (177)	L	2 (Mod)	**B**
HG 1c	83	-	L	5 (1200)	M	-	L	-	**D**
HG 1d	105	16	M	1 (370)	L	3 (717)	M	-	**D**
HG 2a	547	181	H	18 (11145)	H	23 (na)	H	2 (Lim)	**A**
HG 2b	319	95	H	22 (14702)	H	13 (1891)	H	-	**A**
HG 3	356	270	H	2 (Ext)	H	12+ (Ext)	H	5 (Ext)	**A**
HG 4a	274	231	H	7 (Mod)	M	4 (Mod)	M	4 (Lim)	**C**
HG 4b	109	52	M	2 (Mod-Ex)	M-H	7 (Mod)	M-H	2 (Ext)	**B**
HG 5	163	30	L	3 (Mod)	M-L	2 (Mod)	M-L	2 (Lim)	**D**
HG 6	364	13	L	3 (Ext)	H	20 (Ext)	H	1 (Ext)	**A**
HG 7a	681	17	M	11 (7650)	M	19 (na)	M-H	1 (Lim)	**C**

Shoreline Unit	Length of shoreline (km)	Rare Species/ Comm. (#)	Rarity Rating	High-Quality Areas (# - size-ha)	High-Quality Areas Rating	Coastal Wetlands (# - size-ha)	Coastal Wetlands Rating	Important Bird Areas (# - extent)	Criterion 1 (Special Interest) Ranking
HG 7b	308	40	H	13 (22436)	H	1 (71)	L	1 (Lim)	**B**
HG 7c	96	7	M	2 (434)	M	3 (309)	L	-	**D**
HG 8a	743	22	H	8 (26949)	H	2 (559)	L	-	**B**
HG 9	170	33	H	22 (73000)	H	2 (305)	L	3 (Lim)	**B**
HG 10	243	9	M	6 (2600)	H	12 (2719)	H	2 (Mod)	**B**
M 1	242	296	H	3 (Ext)	H	2+ (Mod)	M	2 (Mod)	**B**
M 2a	329	392	H	5 (Ext)	H	3 (Mod)	M	3 (Lim)	**B**
M 2b	293	403	H	4 (Ext)	H	3 (Mod)	M	2 (Mod)	**B**
M 3	375	73	M	9 (Mod)	M	11 (Ext)	H	4 (Lim)	**C**
M 4a	176	78	M	3 (Lim)	L	Lim	L	-	**D**
M 4b	135	405	H	1 (Lim)	L	Lim	L	1 (Lim)	**C**
M 5	131	91	M	4 (Lim)	L	Lim	L	2 (Ext)	**C**
M 6a	130	90	M	5 (Lim)	M-L	4 (Lim)	M-L	1 (Lim)	**D**
M 6b	268	144	H	13 (Ext)	H	7 (Lim)	M-L	4 (Ext)	**A**
M 6c	77	137	H	2 (Mod)	M	Lim	L	2 (Mod)	**B**
M 7a	185	124	H	6 (Mod)	M	Lim	L	3 (Lim)	**C**
M 7b	233	30	M	2 (Ext)	H	Lim	L	-	**C**
S 1	687	97	M	9 (Ext)	H	214 (9089)	VH	2 (Mod)	**A**

Shoreline Unit	Length of shoreline (km)	Rare Species/ Comm. (#)	Rarity Rating	High-Quality Areas (# - size-ha)	High-Quality Areas Rating	Coastal Wetlands (# - size-ha)	Coastal Wetlands Rating	Important Bird Areas (# - extent)	Criterion 1 (Special Interest) Ranking
S 2	383	17	L	8 (4465)	M	14 (Mod)	H	3 (Mod)	**C**
S 3a	301	3	L	4 (2305)	M	1 (Lim)	L	-	**D**
S 3b	587	6	L	5 (72210)	H	-	L	-	**C**
S 4a	338	2	L	4 (1474)	L	3 (349)	M	-	**D**
S 4b	498	273	H	1 (Ext)	H	3 (Lim)	L	1 (Ext)	**A**
S 4c	1145	3	L	6 (59073)	H	3 (Lim)	L	-	**C**
S 5a	83	147	H	1 (Mod)	M	Lim	L	2 (Mod)	**C**
S 5b	266	42	M	10 (Ext)	H	Lim	L	1 (Lim)	**C**
S 6a	97	143	H	2 (Ext)	H	2 (Mod)	M	1 (Ext)	**A**
S 6b	21	-	L	1 (Lim)	L	Lim	L	-	**D**
S 6c	498	9	L	4 (Ext)	H	12 (4170+)	H	1 (Ext)	**A**
S 7a	139	-	L	4 (Mod)	M	Lim	L	1 (Mod)	**D**
S 7b	154	39	M	2 (Ext)	H	2 (Lim)	L	1 (Lim)	**C**
S 7c	277	32	M	6 (Mod)	M	12 (3300+)	H	1 (Lim)	**C**
S 7d	237	6	L	7 (Mod)	M	7 (Mod)	M	1 (Lim)	**D**
S 7e	130	98	M	5 (Ext)	H	Lim	L	4 (Lim)	**C**

[insert Figure 2: Summary map of Criterion 1 ranking - file crit1_c]

3.2 Evaluating Criterion 2: Diversity of Habitats, Communities and Species

This criterion is based on the simple premise that biodiversity can be protected most efficiently by protecting landscapes with the highest diversity of species and genetic resources. Sometimes species diversity can be measured directly, for example by documenting the number of kinds of breeding birds or spawning fish within a given area. In many cases, however, these data are incomplete or fragmentary. Because species and genetic diversity is closely linked to habitat diversity, indirect measures such as the relative diversity of landforms or community types are also used as reliable indicators to compare shoreline units within this criterion.

Three primary data sets were analyzed to assist in assigning rankings to each shoreline unit for this criterion:

15. A shoreline diversity index, based on combinations of shoreline geomorphology and subaqueous substrate types within each shoreline unit.

16. The complexity of shoreline shape, considering the presence of peninsulas or points, offshore islands and shoals.

17. An index of the relative number of fish species known to have spawning or nursery habitat within nearshore waters, including coastal wetlands.

Each of these three data sets and an explanation of how they were used is outlined below. A number of other data sources could be used to further refine the application of this criterion in future, such as:

18. The number of landform types (based on surficial physiographic types) occurring within 1 km of the shoreline within each shoreline unit.

19. The number of known vegetation community types within 1 km of the shore, using a standardized system of community classification currently under development.

20. The number of species of breeding birds, reptiles and amphibians, or vascular plants, based on atlas data on a 10-km square grid system.

21. The relative species diversity of nearshore benthic invertebrates, using data from long-term monitoring stations recently established throughout the Great Lakes.

Where exceptional levels of diversity in one of these features has been documented for specific sites along the Great Lakes coast, they are noted and considered as part of the ranking process, but with the recognition that further refinements would be beneficial.

Applying guidelines to the data sets:

Shoreline diversity:

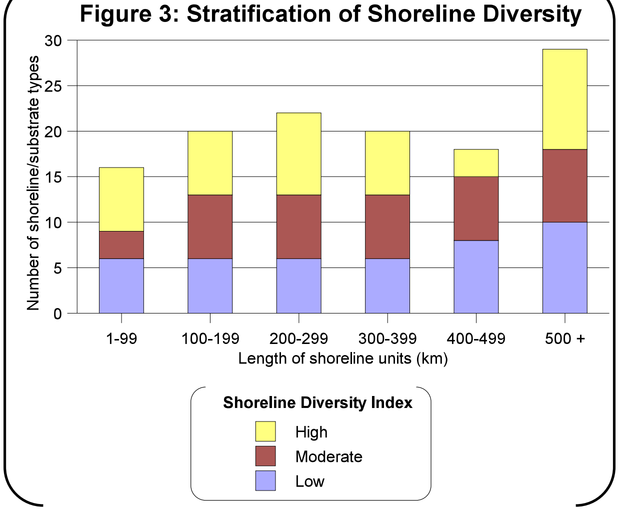
A shoreline diversity index was calculated using medium resolution vector shoreline data compiled by the United States Army Corps of Engineers (USACE) and Environment Canada (http://www.glerl.noaa.gov/data/char/). This classification, originally developed to quantify the influence of lake-level effects on shoreline erosion, describes both the shoreline geomorphology (17 classes) and the subaqueous type (6 classes) of reaches along the U.S. and Canadian shoreline (International Joint Commission 1993). A shoreline diversity index counted the number of different combinations of shoreline geomorphology and subaqueous types within each shoreline unit; shoreline reaches characterized as "artificial" were left out of the calculations.

As shown in Table 3, the 70 shoreline units have a range in the number of shoreline geomorphology and subaqueous substrate type combinations from 3 to 29. While longer shoreline units tend to have more combinations, this does not hold true for many units. To clearly identify shoreline units with relatively high shoreline diversity, the 70 units were stratified as follows:

Units from 1-99 km in length (12 units), with a range of combinations from 3 to 16;
Units from 100-199 km in length (24 units), with a range from 4 to 20 combinations;
Units from 200-299 km in length (11 units), with a range from 4 to 22 combinations;
Units from 300-399 km in length (10 units), with a range from 3 to 20 combinations;
Units from 400-499 km in length (4 units), with a range from 3 to 18 combinations;
Units more than 500 km in length (9 units), with a range from 8 to 29 combinations.

Within each of these strata, break points for a high/moderate/low index of shoreline diversity were established, to place roughly one-third of the units in each class, or to recognize major discontinuities in the range of combinations. The distribution of these break points is shown in Figure 3 below, and the resulting diversity index is shown in Table 3 and Figure 4.

Figure 3: Stratification of Shoreline Diversity



[insert Figure 4: shoreline diversity index - file noname shorediv]

Shoreline Complexity:

Shoreline units were classified as high, moderate, or low shoreline complexity based on a visual scanning of coastal mapping. Units with large numbers of islands, irregular peninsulas and bays, and a high degree of interspersion among various shoreline types (such as rocky headlands interspersed with sandy beaches) ranked as high. Units with relatively straight shorelines, few or no offshore islands or shoals, and relatively low interspersion of shoreline types ranked low. Units with a moderate rank usually have at least one major peninsula or island, with a moderate degree of interspersion. The shoreline complexity ratings assigned for each unit are shown in Table 3.

Fish Spawning/Nursery Areas:

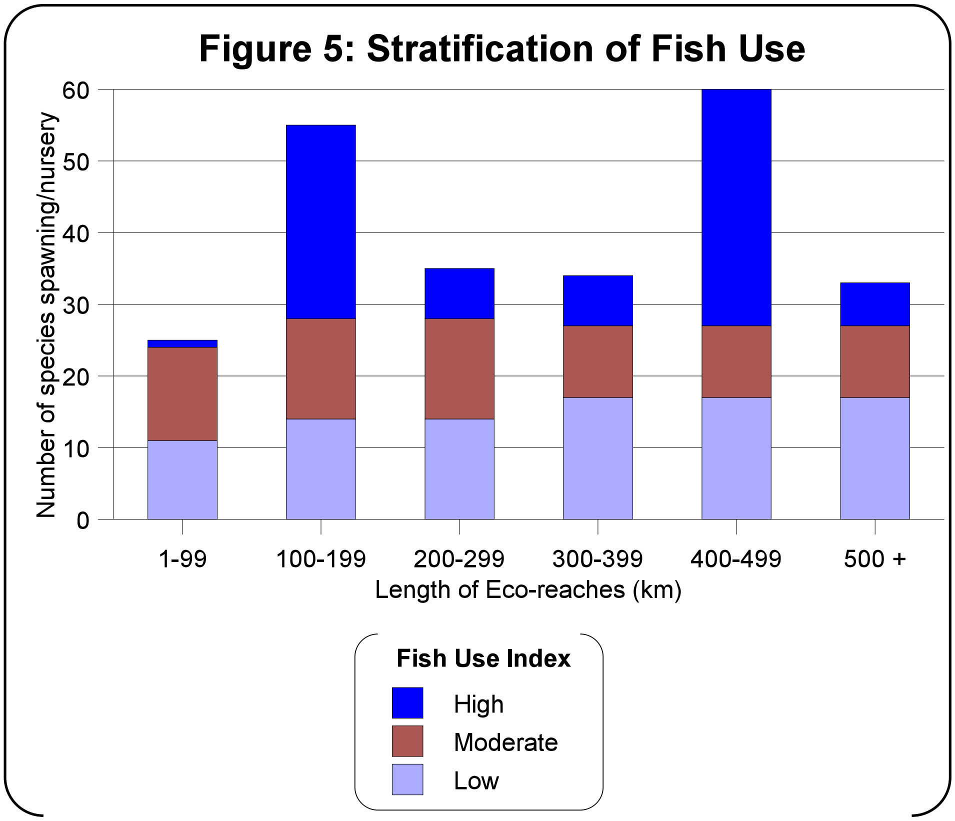
The Coastal Wetlands BIA report (Chow-Fraser and Albert 1998) included a tabulation of the number of fish species using each of the eco-reaches defined in that report for spawning and for nursery habitat. This information, which was collected by super-imposing the eco-reaches onto fish atlas maps (Goodyear et al. 1982), presented data for tributary use and for littoral areas up to 9 feet deep, presumably including all coastal wetlands. Within Table 3, only the littoral information is used, with the two numbers indicating the total number of fish species spawning and the total number with nursery areas respectively.

Since this report further subdivides some of the 1998 coastal eco-reaches into smaller shoreline units, the fish data for some areas are presented only as an average over these broader units, without knowing what degree of variation exists. This reduces the reliability of this data set in some areas, such as the south shore of Lake Erie. In addition, in some areas this data set may be significantly influenced by the degree of knowledge about fish use, particularly in more remote areas where fewer studies have been completed.

To more clearly identify shoreline units with a relatively high fish use diversity, the 44 1998 eco-reach units were stratified in a similar way to the shoreline diversity index. Both fish spawning and nursery use was considered, with the larger species number being used for each unit (e.g. if an eco-reach had 12 spawning species and 9 nursery species, the number 12 was used). This stratification (based on the 44 eco-reaches from the 1998 Coastal Wetlands report) yielded:

2 eco-reaches from 1-99 km in length, with a range of fish use from 21 to 25 species;
11 eco-reaches from 100-199 km in length, with a range from 6 to 55 species;
5 eco-reaches from 200-299 km in length, with a range from 4 to 35 species;
8 eco-reaches from 300-399 km in length, with a range from 6 to 34 species;
6 eco-reaches from 400-499 km in length, with a range from 9 to 60 species;
12 eco-reaches over 500 km in length, with a range from 2 to 33 species.

Within each of these strata, break points for a high/moderate/low index of fish use diversity were established, to place roughly one-third of the eco-reaches in each class. The distribution of these break points is shown in Figure 5 below, and the resulting ratings are shown in Table 3 and Figure 6.



Guidelines for ranking:

The shoreline diversity index, shoreline complexity rating, and fish use index provided the basis for the Criterion 2 (diversity) ranking for each shoreline unit. Units were ranked as A if they had at least two high scores, as B if they had at least one high and one moderate score, as C if they had one high + two low scores, or three moderate scores, and as D if they had lower values. Five shoreline units with exceptional breeding bird densities (from Chow-Fraser and Albert 1998) were bumped up one ranking to reflect this added element of diversity.

These summary rankings for Criterion 2 are shown in the last column of Table 3, and in map form in Figure 7.

[insert Figure 6: Distribution of fish use index - file fishuse]

Table 3: Ranking of Shoreline Units based on Criterion 2

Shoreline Unit	Length of shoreline (km)	Shoreline Diversity (# of types)	Shoreline Diversity Index Class	Shoreline Complexity	Fish Spawn/ Nursery (# of spp)	Fish Use Index Class	Other Known Diversity Factors	Criterion 2 (Diversity) Ranking
OS 1	588	29	H	High	19/15	M		**A**
OS 2	487	10	M	High	9/9	L		**B**
OS 3a	961	23	H	High	30/16	H	Exceptional breeding bird diversity	**A**
OS 3b	303	13	M	High	21/0	M		**B**
OS 4a	253	15	H	Low		H		**A**
OS 4b	144	17	H	Low	35/19	H	Exceptional breeding bird diversity	**A**
OS 4c	50	16	H	High		H		**A**
OS 5	136	12	H	Low	22/9	M		**B**
OS 6	191	12	M	Moderate	29/27	H		**B**
OS 7	42	7	M	Low	21/0	M		**D**
E 1	166	9	M	Moderate	11/8	L		**D**
E 2	161	17	H	Low	10/16	L		**C**
E 3	117	4	L	High	34/32	H	High breeding bird diversity	**A**
E4	222	12	M	Moderate	15/5	M		**C**
E 5	105	11	M	Moderate	12/9	L		**D**
E6a	427	18	H	Moderate	55/51	H		**A**
E6b	154	15	H	High	55/51	H		**A**
E 7a	48	8	M	Low		H		**B**

Shoreline Unit	Length of shoreline (km)	Shoreline Diversity (# of types)	Shoreline Diversity Index Class	Shoreline Complexity	Fish Spawn/ Nursery (# of spp)	Fish Use Index Class	Other Known Diversity Factors	Criterion 2 (Diversity) Ranking
E7b	198	20	H	Low		H		**A**
E7c	59	6	L	Moderate		H		**B**
E 7d	166	11	M	Low	53/60	H		**B**
SC 1	178	5	L	Moderate	26/20	M		**D**
SC 2	666	11	M	Moderate	33/24	H		**B**
SC 3	88	9	M	Low	18/25	H		**B**
HG 1a	175	14	H	Low	20/14	M	High breeding bird diversity	**B**
HG 1b	99	11	H	Moderate	20/14	M	High breeding bird diversity	**B**
HG 1c	83	5	L	Low	20/14	M	High breeding bird diversity	**D**
HG 1d	105	6	L	Moderate	20/14	M	High breeding bird diversity	**D**
HG 2a	547	8	L	High	11/17	L	Exceptional breeding bird diversity	**B**
HG 2b	319	3	L	High	11/17	L	Exceptional breeding bird diversity	**B**
HG 3	356	8	M	High	6/5	L		**B**
HG 4a	274	10	M	Moderate	20/14	M		**C**
HG 4b	109	10	M	High	20/14	M		**B**
HG 5	163	11	M	Low-Mod	30/9	H		**B**
HG 6	364	5	L	Moderate	34/12	H		**B**
HG 7a	681	11	M	High	12/13	L	Exceptional breeding bird diversity	**A**

Shoreline Unit	Length of shoreline (km)	Shoreline Diversity (# of types)	Shoreline Diversity Index Class	Shoreline Complexity	Fish Spawn/ Nursery (# of spp)	Fish Use Index Class	Other Known Diversity Factors	Criterion 2 (Diversity) Ranking
HG 7b	308	11	M	High		L		**A**
HG 7c	96	9	M	Low		L		**C**
HG 8a	743	10	L	High	6/2	L		**C**
HG 9	170	5	L	High	6/1	L	High breeding bird diversity	**B**
HG 10	243	6	L	High	4/0	L		**C**
M 1	242	4	L	High	35/5	H		**A**
M 2a	329	10	M	High	26/18	M		**B**
M 2b	293	16	H	High		M		**A**
M 3	375	12	M	Moderate	26/22	M		**C**
M 4a	176	10	M	Low	28/25	H		**B**
M 4b	135	14	H	Low		H		**A**
M 5	131	6	L	Low	26/19	M		**D**
M 6a	130	4	L	Low	29/29 (with M 6c)	H		**C**
M 6b	268	8	M	Moderate	22/15	M		**C**
M 6c	77	7	M	Low	29/29 (with M 6a)	H		**B**
M 7a	185	11	M	Moderate	9/5	L		**D**
M 7b	233	5	L	High		L		**C**
S 1	687	19	H	High	14/9	L		**A**

Shoreline Unit	Length of shoreline (km)	Shoreline Diversity (# of types)	Shoreline Diversity Index Class	Shoreline Complexity	Fish Spawn/ Nursery (# of spp)	Fish Use Index Class	Other Known Diversity Factors	Criterion 2 (Diversity) Ranking
S 2	383	20	H	High	24/6	M		**A**
S 3a	301	6	L	High	2/0	L		**C**
S 3b	587	8	L	Mod-High		L		**C**
S 4a	338	14	H	Mod-High	6/4	L		**A**
S 4b	498	3	L	High		L		**C**
S 4c	1145	14	M	High		L		**B**
S 5a	83	7	M	Low	18/6	M		**D**
S 5b	266	8	M	Low		M		**D**
S 6a	97	9	M	Low	20/13	M		**D**
S 6b	21	5	L	Low		M		**D**
S 6c	498	12	M	High		M		**B**
S 7a	139	11	M	Low	17/14 (with S7c-e)	L		**D**
S 7b	154	9	M	Low		L		**D**
S 7c	277	22	H	Moderate		L		**B**
S 7d	237	11	M	Low-Mod		L		**D**
S 7e	130	6	L	Low		L		**D**

[insert Figure 7: Summary map of Criterion 2 ranking - file crit2_c]

3.3 Evaluating Criterion 3: Productivity and Integrity

The role and significance of nearshore habitats in sustaining biodiversity is influenced by several factors, including the physical characteristics of the area and the degree to which habitat functions have been impaired. Across the Great Lakes basin, some shoreline areas sustain a range and abundance of terrestrial and aquatic life that is close to historic conditions. Other areas have been substantially modified by physical alterations, pollution, or exotic species, and their ecological productivity is largely expressed through simplified or artificial communities.

One example of this distinction between ecosystems with historic or "natural" levels of productivity and integrity and those that have been impaired occurs in the Lake St. Clair - western Lake Erie corridor. This area once had the richest and most diverse assemblage of unionids (large freshwater clams) in North America (Goodrich and van der Schalie 1932). After the introduction of zebra mussels, these productive unionid populations quickly declined to almost zero, and the productivity of these habitats was increasingly expressed through rapidly expanding populations of the non-native zebra mussels. In the words of Edsall and Charlton (1996): "*Biodiversity has declined sharply as the functional community has basically shifted from a stable, slow-growing, multispecies unionid community with a minor influence on the ecosystem to a single-taxon population of zebra mussels with a relatively high turnover rate that strongly affects ecosystem dynamics*."

While virtually every corner of the Great Lakes system has suffered some impairment to its ecological functions, the regions selected as Biodiversity Investment Areas should be sufficiently intact that abundance levels and species assemblages of fish, invertebrates, wildlife or vegetation bear at least some resemblance to historic conditions. BIAs may also represent areas that provide essential conditions or critical habitats for specific life stages such as spawning or migratory staging. These areas, which Steedman and Regier (1987) called "centres of organization", may be far more ecologically significant than their small size would suggest, and frequently tend to occur in shallow nearshore areas (Edsall and Charlton 1996). For example, of the 139 Great Lakes fish species reviewed by Lane et al. (1996), all but five species typically use shallow waters as nursery habitat.

Assigning rankings to the shoreline units for this criterion is difficult, because comparable information on productivity and historic conditions is fragmentary and incomplete. Koonce et al. (1998) suggested that the development of habitat suitability mapping for individual fish species, based on combinations of depth, substrate, and cover, would provide the necessary basis to compare aquatic areas for BIA designation. While this approach will provide greater confidence in results in the longer term, several datasets now available have been used to develop a first approximation of rankings for this criteria:

22. A compilation of the percentage of hardened shoreline within each shoreline unit, as a rough index of the degree of intactness of natural shoreline processes and the physical modification of nearshore habitats.

23. Mapping of the degree of trophic degradation of nearshore waters from historic conditions, since nutrient enrichment has significantly altered ecosystem dynamics.

24. An estimation of the degree of coastal wetland habitat loss within each shoreline unit, as one measure of the current extent of significant habitat patches compared to historic conditions.

A number of other data sources could be used to further refine the application of this criterion in future:

25. Documentation of the extent, pattern, and condition of remaining terrestrial habitats such as forests along the shoreline area.

26. Mapping of critical habitats of major significance for native species, such as lake trout, lake whitefish or walleye spawning areas, staging areas for migrant birds (waterfowl, shorebirds, passerines), or wintering concentration areas for waterfowl.

27. Habitat types known to typically support high levels of productivity for native species, such as coastal marshes, sheltered embayments, and shallow aquatic habitats with gravel, sand, and silt substrates.

28. The diversity and abundance of benthic invertebrate communities, which has been proposed as one of the indicators of nearshore water quality and has monitoring reference sites already established (Environment Canada and USEPA 1999).

29. The percentage of non-native vascular plants within terrestrial or wetland communities, or of non-native species in nearshore fish communities.

30. The degree of aquatic habitat fragmentation by dams or barriers on lower tributaries.

Where information on these factors is available for specific shoreline units, it has been noted and considered as part of the ranking process, but with the recognition that further refinements would be beneficial.

Hardened shorelines:

Within each shoreline unit, an estimate of the percent of shoreline that has been hardened was calculated using medium resolution vector shoreline data compiled by the United States Army Corps of Engineers (USACE) and Environment Canada (http://www.glerl.noaa.gov/data/char/). The length of shoreline characterized by the Erosion Process Task Group as "highly protected" (i.e. between 70-100% fortified against erosion) was divided into the total shoreline length for each shoreline unit. This number was rounded to the nearest percent for each shoreline unit and included in Table 4.

From this data, a four-level index of shoreline hardening was developed:

VH - very high: 50% + of shoreline unit in “highly protected” category
H - high: 21 - 49% in “highly protected” category
M - moderate: 7 - 20% in “highly protected” category
L - low: less than 6% in “highly protected” category

Trophic degradation:

Except in shallow bays and marshes, the Great Lakes were oligotrophic before European settlement and industrialization (Environment Canada et al. 1987). Excessive nutrients resulted in degradation at various levels in all of the lakes, and control programs have resulted in significant recovery in the past two decades. Information on current tropic status was taken from the The Great Lakes Environmental Atlas and Resource Book (Environment Canada et al.1987). Since it is possible that trophic conditions in some nearshore areas have changed since the date of this publication, particularly in Lakes Ontario and Erie, more recent phosphorus surveillance data and summary reports were consulted to update this information (OMOE 1999; Duncan Boyd, pers. comm.).

Ratings of trophic degradation in Table 4 are based on the following:

None: coastal waters mapped as oligotrophic

Marginal: coastal waters mapped as entirely or mostly oligotrophic/mesotrophic

Moderate: coastal waters mapped as entirely or mostly mesotrophic, in some cases with small sections of eutrophic included

Significant: coastal waters include substantial sections mapped as eutrophic or mesotrophic/eutrophic

Historic wetland loss:

Coastal wetland habitats are recognized as important centres of organization for the nearshore ecosystem, with over 90% of Great Lakes fish species dependent on them for some part of their life cycle (Whillans 1987). Coastal wetland habitats support diverse invertebrate assemblages (Kreiger 1992), with a greater biomass and numbers of macroinvertebrates in sediments of vegetated wetlands than in unvegetated sediments (Brady 1992).

Along the shores of the lower Great Lakes, wetland loss since the time of European settlement has been considerable. This loss is highly variable from place to place, with areas of high urban or agricultural pressures generally having the highest rates of historic loss. In most areas, the degree of wetland habitat loss is similar to the loss of terrestrial nearshore habitats in the adjacent area, so that this factor provides an approximation of the degree of disruption from physical habitat loss and fragmentation throughout the nearshore ecosystem.

In most areas, detailed numerical data is not available to document the extent of coastal wetland loss. However, Maynard and Wilcox (1996) provided a description on the status of coastal wetlands for each of the Great Lakes and connecting channels, and Chow-Fraser and Albert (1998) describe coastal wetland distribution and characteristics within each of their coastal eco-reaches. For some areas such as the Lake Ontario and Lake St. Clair Canadian shorelines, numerical data is available (McCullough 1981; Whillans 1982). Data and descriptive text from these sources was used to rate historic wetland loss within each shoreline unit as:

H - high: over 40% known loss, or described as high or very high loss
M - moderate: 11-39% known loss, or described as partial loss
L - low: 10% or less known loss, or described as little or no loss

These ratings are shown in Table 4.

Guidelines for ranking:

The hardened shoreline index, trophic degradation rating, and historic wetland loss rating provided the basis for the Criterion 3 (Productivity and Integrity) ranking for each shoreline unit. Other factors were considered where they were available, such as known significant fish spawning and bird staging areas (from Smith 1987) and in a few cases resulted in the ranking being raised by a maximum of one level.

Units were ranked A if:

Trophic degradation was rated as None, and
Hardened shoreline was rated as Low, and
Wetlands loss was rated as Low.

Units were ranked B if:

Trophic degradation was rated as None, Marginal or Moderate, and
Only one of the other two ratings was Moderate, with the other Low.

Units were ranked C if:

Any one of the three ratings was High (Significant for trophic degradation), or
Any two, or all three, of the ratings were Moderate.

Units were ranked D if:

Any two or all three of the ratings were High (Significant for trophic degradation), or
The hardened shoreline rating was Very High.

These summary rankings for Criterion 3 are shown in the last column of Table 4 and in Figure 8.

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Table 4: Ranking of Shoreline Units based on Criterion 3

Shoreline Unit	Length of shoreline (km)	% hardened shoreline	Hardened shoreline rating	Trophic degradation status	Historic wetlands loss	Other Known Productivity/Integrity Factors	Criterion 3 (Prod/Integ) Ranking
OS 1	588	25	H	Marginal	M		**C**
OS 2	487	0	L	Marginal	M	Waterfowl concentrations; fish spawning area	**B**
OS 3a	961	3	L	Moderate	M-H	Spawning area for lake trout, whitefish; waterfowl staging area	**B**
OS 3b	303	0	L	None	M		**B**
OS 4a	253	50	VH	Moderate	H	Waterfowl staging area	**D**
OS 4b	144	16	M	None	M		**C**
OS 4c	50	10	M	None	L	Waterfowl, shorebird and landbird staging area	**B**
OS 5	136	1	L	Moderate	M		**B**
OS 6	191	4	L	None	H		**C**
OS 7	42	0	L	None	M		**B**
E 1	166	47	VH	Significant	H	Wintering area for gulls	**C**
E 2	161	34	H	Marginal	M-H		**C**
E 3	117	0	L	Marginal	M	Waterfowl and shorebird staging area; fish spawning and nursery area	**B**
E4	222	8	M	Moderate	H	Waterfowl and landbird staging area at Rondeau	**C**
E 5	105	35	H	Significant	H	Landbird staging areas	**C**
E6a	427	21	H	Significant	H	Waterfowl staging area	**C**
E6b	154	11	M	Significant	M	Waterfowl and landbird staging area; fish spawning area	**B**
E 7a	48	21	H	Significant	H		**D**

Shoreline Unit	Length of shoreline (km)	% hardened shoreline	Hardened shoreline rating	Trophic degradation status	Historic wetlands loss	Other Known Productivity/Integrity Factors	Criterion 3 (Prod/Integ) Ranking
E7b	198	33	H	Moderate	H		**D**
E7c	59	25	H	Moderate	M	Landbird staging area	**C**
E 7d	166	19	M	Moderate	M-H		**C**
SC 1	178	50	VH	Moderate	H	Waterfowl staging area	**D**
SC 2	666	15	M	Significant	H	Waterfowl staging area	**C**
SC 3	88	70	VH	Moderate	M-H		**D**
HG 1a	175	4	L	Marginal	L		**B**
HG 1b	99	12	M	None	M-L		**B**
HG 1c	83	10	M	None	L		**B**
HG 1d	105	6	L	None	L		**A**
HG 2a	547	0	L	None	L		**A**
HG 2b	319	0	L	None	L	Fish spawning areas	**A**
HG 3	356	2	L	None	L		**A**
HG 4a	274	2	L	None	L		**A**
HG 4b	109	4	L	Marginal	L		**B**
HG 5	163	5	L	Marginal	M-L		**B**
HG 6	364	0	L	Significant	M-H		**C**
HG 7a	681	0	L	None	L	Waterfowl staging area	**A**

Shoreline Unit	Length of shoreline (km)	% hardened shoreline	Hardened shoreline rating	Trophic degradation status	Historic wetlands loss	Other Known Productivity/Integrity Factors	Criterion 3 (Prod/Integ) Ranking
HG 7b	308	2	L	None	L	Fish spawning areas	**A**
HG 7c	96	8	M	None	L		**A**
HG 8a	743	0	L	None	L		**A**
HG 9	170	0	L	None	L	Waterfowl staging; fish spawning	**A**
HG 10	243	8	M	Moderate	M-H	Waterfowl staging area	**B**
M 1	242	0	L	None	L		**A**
M 2a	329	9	M	Moderate	M		**C**
M 2b	293	0	L	None	M		**B**
M 3	375	5	L	Significant	H		**C**
M 4a	176	15	M	None	H		**C**
M 4b	135	26	H	Moderate	H		**D**
M 5	131	81	VH	Moderate	H		**D**
M 6a	130	1	L	Marginal	M		**B**
M 6b	268	0	L	Marginal	L		**B**
M 6c	77	14	M	Moderate	M		**C**
M 7a	185	0	L	Marginal	L		**B**
M 7b	233	0	L	Marginal	L		**B**
S 1	687	2	L	None	L		**A**
S 2	383	4	L	None	L	Fish spawning; waterfowl and landbird staging	**A**

Shoreline Unit	Length of shoreline (km)	% hardened shoreline	Hardened shoreline rating	Trophic degradation status	Historic wetlands loss	Other Known Productivity/Integrity Factors	Criterion 3 (Prod/Integ) Ranking
S 3a	301	1	L	None	L	Fish spawning	**A**
S 3b	587	0	L	None	L	Fish spawning	**A**
S 4a	338	7	M	Marginal	M-L	Fish spawning; waterfowl staging	**B**
S 4b	498	0	L	None	L		**A**
S 4c	1145	0	L	None	L	Fish spawning; waterfowl and landbird staging	**A**
S 5a	83	42	H	Marginal	L		**C**
S 5b	266	3	L	None	L		**A**
S 6a	97	48	H	Marginal	M-L		**C**
S 6b	21	0	L	Marginal	L		**B**
S 6c	498	4	L	None	L		**A**
S 7a	139	1	L	None	L		**A**
S 7b	154	1	L	None	L		**A**
S 7c	277	1	L	None	L		**A**
S 7d	237	5	L	None	L		**A**
S 7e	130	0	L	None	L		**A**

[insert Figure 8: Summary map of Criterion 3 ranking - file crit3_c]

4.0 Mapping Potential Integrated Biodiversity Investment Areas

The results of the rankings for each of the three criteria have been compiled to produce composite rankings, as shown in Table 5. Shoreline units are evaluated on the basis of these composite rankings in a relative sense, ranging from the highest value unit ranked as AAA, to the lowest value unit at DDD. For the purposes of this analysis, ranking combinations with equivalent levels of value have been grouped together.

Table 5: Composite rankings for Great Lakes shoreline units

Tier	Composite ranking combination	Shoreline units within group	Total length of shoreline units in group (km)	% of total shoreline length
1	AAA	S1	687	3.6%
2	AAB	OS3a, OS4c, E3, E6b, HG2a, HG2b, HG3, HG7b, M1, S6c	3552	18.5%
3	AAC, ABB	E6a, HG7a, HG9, M2b, S2, S4b	2452	12.8%
4	AAD, ABC, BBB	OS1, OS2, OS3b, E7c, SC2, HG1b, HG4B, HG6, HG8a, M6b, S4c, S7c	5108	26.7%
5	ABD, ACC, BBC	OS4b, HG4a, HG10, M2a, M6c, S3b, S4a	1992	10.4%
6	All Other Combinations	34 units	5432	28.0%

These composite rankings provide an integrated, data-based guide for identifying priority habitat areas that could be designated as Biodiversity Investment Areas. The top two tiers encompass just over 22% of the shoreline length in 11 shoreline units, as shown on Figure 9. Their distribution dramatically illustrates the importance of the “Mackinac-Manitoulin Arch” - the crescent of significant biodiversity sites that encompasses the northern parts of Lake Michigan, Lake Huron, and Georgian Bay.

Adding the next tier of shoreline units (Tier 3) brings the total shoreline encompassed by these priority units to over one-third of the Great Lakes coast, and broadens the distribution across other sections of the lakes. Other individual shoreline units in Tiers 4 and 5 highlight some sections on individual lakes which rank more highly than the rest.

This analysis points out some very significant shoreline areas that may have been overlooked in previous BIA studies. In particular, the St. Mary’s River (Unit S1) and the nearby sections of Lake Superior (Unit S2) and Lake Michigan (Unit M1) receive much higher recognition through this study. As well, the importance of the St. Lawrence River (Units OS1, OS2) and the Kettle Point to Grand Bend area of Lake Huron (Unit HG1b) is illustrated, suggesting that these areas warrant further study. On the other hand, a few areas that were previously included in recommended BIAs, such as the Detroit River (Unit SC1) and Chicago Wilderness (Units M5, M6c) and eastern Lake Superior (Unit S3b) receive only medium ranks in this integrated system.

Figure 9: Composite ranking of Great Lakes shoreline units

5.0 Opportunities and Future Directions

Future directions related to an integrated set of BIAs for the Great Lakes should incorporate further actions to address information gaps and refine BIA identification, measures to assess and respond to threats to their integrity, and encouraging opportunities to enhance the protection of these high-quality areas at several scales. The following points are intended to suggest some of the most fruitful future directions:

- The mapping produced through this study is based on the best data available, but should be regarded as dynamic and continue to accommodate new scientific findings as additional digital data sets are developed. The data contributing to the assessment of Criterion 3, Productivity/Integrity, is most in need of refinement, since all three major data sets are based primarily on the degree of impairment to historical conditions, rather than on direct measures of current productivity or ecosystem integrity.

  While the aquatic component related to BIA identification captures well the diversity in physical environments, the influence of dynamic animal communities, as outlined by Koonce et al.(1998) needs considerably more work. The fish spawning and nursery data is dated and somewhat uneven, and needs to be revised to correspond to the smaller shoreline units used in this study. Additional measures of aquatic productivity, such as comparative studies of nearshore benthic invertebrates, would be very helpful.

  The conceptual model put forward in the 1998 Aquatic Biodiversity Investment Areas paper (Koonce et al. 1998), which links biodiversity, habitat attributes, and spatial units, is consistent with the approach taken in this study, and should be pursued further. In the longer term, a habitat supply analysis for individual species or groups of fish, as proposed by Koonce et al., would contribute significantly to an understanding of aquatic productivity.

  Other priority areas for refinement include the American data set on rare species and communities, the possible addition of a data set on endemic species, and more up-to-date wetlands mapping on the U.S. side of the basin.

- A more detailed review of values and potential BIA boundaries should be carried out for shoreline units within the top four tiers. For 21 of these 29 units, much of this analysis of values, threats, and protection needs has already been carried out (Reid et al. 1998), although additional information on aquatic and wetland values should be added where appropriate. A similar analysis should be completed for the following other priority areas:

  St. Lawrence River corridor
  Kettle Point - Grand Bend area of southern Lake Huron
  Lake Huron North Channel
  Mackinac - Lake Michigan north shore
  St. Mary's River
  Batchawana Bay - Whitefish Bay

- The social context within BIAs is a very important factor, not just in influencing their current status, but also their future. In large part, it is the activities of the people who live within BIAs, and the industries that operate there, which pose the greatest threats to their integrity. Equally, it is the commitment of local people, agencies, and industries that is so vital to maintaining their future quality. Raising the level of local awareness about the special qualities of BIAs, and enlisting local support and participation in their conservation, is an essential part of any future strategy.

- As noted above, the majority of the BIAs have been examined in detail to identify threats to their integrity (Reid et al. 1999). Several stressors occur repeatedly in BIAs across the Great Lakes basin. Changing land use tops the list, with pressures for second home developments, resource extraction, and recreational uses such as marinas being listed as factors in almost every BIA. The effects of exotic species invasions, and the potential future effects of climate change, are other major concerns.

  The degree of protection for biodiversity values, as well as the opportunity for restoration, varies greatly among BIAs. As demonstrated by the case studies in Appendix A, improved inter-agency coordination is an important goal for all BIAs.

  The long-term monitoring of ecological indicators being developed through the SOLEC and Lakewide Management Planning processes, along with other monitoring programs, will be of assistance in measuring the impact of stresses both within and outside BIAs, and in formulating appropriate responses.

- A considerable amount of very constructive conservation activity is already underway in BIAs across the Great Lakes basin, and the level of that activity appears to be rising. While this study did not include an assessment of local conservation initiatives, even a few examples illustrate the breadth of activity underway.

  On the scenic east coast of Georgian Bay, cottagers associations and municipalities are working to create a unique new kind of Biosphere Reserve, focusing on the productive littoral zone, as a way of countering rising development pressures.

  On Lake Michigan's Door Peninsula, a group of property owners is working to create a Stewardship Council to provide a forum for reconciling environmental and economic goals.

  On the south shore of Manitoulin Island, a collaborative bi-national project involving both non-government and government bodies recently completed the acquisition of over 17,000 acres of alvar and shoreline habitats, the single largest project of its kind ever in the Great Lakes basin.

  In the two years since the last SOLEC conference, the Ontario Living Legacy program, sponsored by the Ministry of Natural Resources, has set aside massive tracts of nearshore lands along Georgian Bay, the Lake Huron north channel, and northern Lake Superior.

This accomplishment was made possible by negotiations between resource industries, environmental groups, and the government, with the outcome endorsed by all participants. The province has now embarked on more detailed planning for the Great Lakes Heritage Coast, stretching from the southeast corner of Georgian Bay to the western boundary of Lake Superior.

- In the past few years, there have been some good beginnings at incorporating biodiversity and habitat protection into Lakewide Management Planning processes. However, while this study highlights the exceptional significance for biodiversity conservation of the Mackinac - Manitoulin arch, a large part of which is located in northern Lake Huron, this lake has to date received little attention for lakewide planning. When binational lakewide planning does proceed for Lake Huron, the importance of these high-quality nearshore environments to maintaining the biological integrity of the Great Lakes ecosystem should be fully considered.

- One of the challenges in protecting the values of BIAs is their complexity, which in turn will often require complex solutions and complex partnerships. Without question, preserving the full complement of biodiversity in the Great Lakes nearshore area requires more than simply cleaning up pollution - it also requires positive, coordinated actions to maintain or improve the natural habitats that support biodiversity. Our collective experience over the past several decades in rehabilitation programs has shown just how difficult and expensive it is to attempt to restore habitats. Protecting the best of the shoreline areas from degradation is a far more effective and far less costly approach.

  BIAs can be used as a tool to guide future investments in these protective actions. They can become a framework for creating shared priorities, paving the way for collaborative action among agencies, communities, and conservation organizations. They can create new opportunities for partnerships with industry, First Nations, and tourism interests. They can create a new vision for management of the Great Lakes, one which includes not only the rehabilitation of the worst shoreline areas, but also the preservation of the best.

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Appendix A: Case Studies

The following three case studies are located within areas considered for designation as Biodiversity Investment Areas, and have been contributed by authors familiar with the values and aspects of the management of each area. At least three themes from the case studies could be highlighted:

- That water acts as an absolutely vital linking feature among the terrestrial, wetland, and aquatic components of these ecosystems;

- That despite multiple designations and active protection programs within each area, they are still under enormous stress from a variety of sources; and

- That they have outstanding potential to act as benchmark areas for future research and adaptive management, thereby contributing significantly to the management of the Great Lakes as a whole.

Long Point, Ontario

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Introduction

The purpose of this report is to provide an overview of the Long Point region, introduce its ecological features and values, linkages among these and provide some thought on challenges and opportunities in terms of planning and management. The overall context for this case study is the value of the Long Point region as a relatively natural, intact ecosystem in the Great Lakes basin. The Long Point region has been recognized as a potential Biodiversity Investment Area (BIA) in recent years in work done for State of the Lakes Ecosystem Conferences (SOLEC). BIAs are seen to be areas or landscapes of exceptional quality at the regional level.

The central message is that Long Point is ecologically a very rich area. It is under considerable stress from inappropriate and ill-planned development and land uses. The result is fragmentation, degradation and loss of habitat. It is critical that these stresses be addressed as soon as possible in order to prevent further degradation of this important area. Now is an appropriate time to re-think and re-focus the many conservation initiatives in the region. Thinking in terms of ecological linkages may provide a new starting point planning, management and decision-making.

Much of the material for this report was obtained from the *Long Point Environmental Folio*, produced by the Heritage Resources Centre, University of Waterloo (Nelson and Wilcox 1996). The Folio brought together information on a variety of topics important to the Long Point region and attempted to make the information accessible and understandable to a wide range of people. The information is intended to be used to help people understand and make better decisions about the environment and future development in the Long Point area.

Long Point: An Overview

Long Point (figure 1) is of unusual importance because it includes the largest area of wildland remaining along the shores of the lower Great Lakes. The Long Point peninsula or spit extends 32 kilometers into Lake Erie and divides the eastern and central basins of the lake. The spit partially encloses Long Point Bay (or the "Outer Bay") and the smaller Inner Bay. It is connected to the mainland by a causeway, constructed in 1928. Long Point is the longest sandy spit on the Great Lakes and is representative of other spits, such as those found at Point Pelee and Rondeau (Stenson 1996). The western shoreline is characterized by 30-40 meter high eroding clay bluffs, with low-lying beaches, wetlands and bluffs to the east. The spit itself consists of extensive marsh areas, sand dunes, forests and beaches.

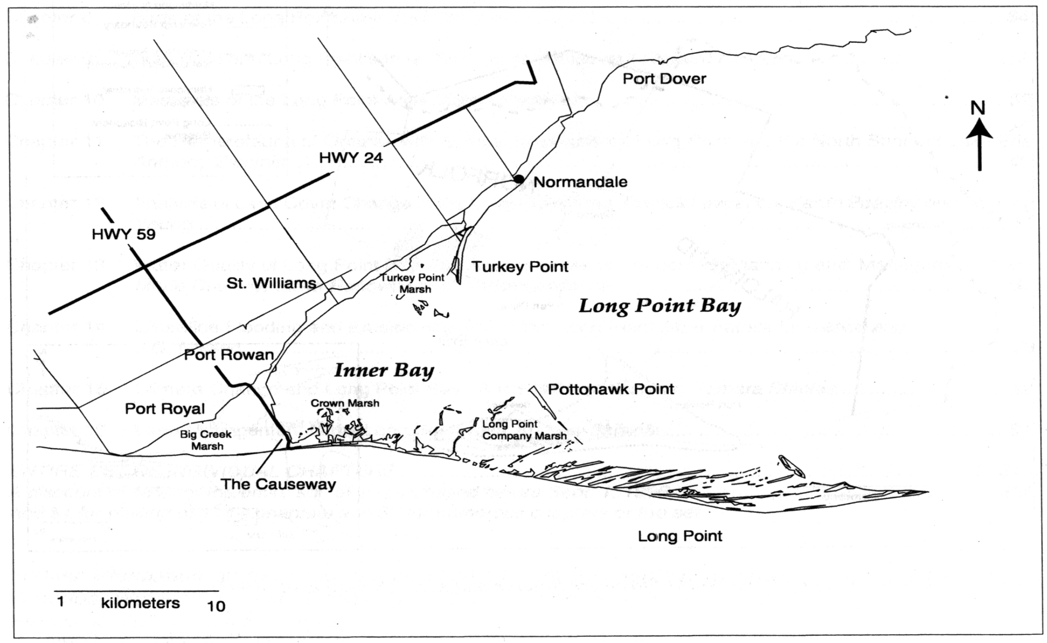

Figure 1. Long Point (Nelson et al. 1996)

Human History and Economics

Archaeological evidence suggests that the Long Point area was used seasonally by Native peoples from circa 1300 to the 1780s (Dakin and Skibicki 1996). In 1784 the British government purchased land in the region from the Mississauga Natives, and settlement of the area by United Empire Loyalists from the United States began. Saw and grist mills played an important role in early settlement of the region. Agriculture was also important and remained the primary economic activity in the region in the nineteenth century. Lumber was exported from the region in the mid-1800s, but intensive cutting resulted in dwindling supplies and by 1900 forests on the mainland had been reduced to 11 percent (Dakin and Skibicki 1996). Commercial fishing peaked between 1896 and 1905.

The Long Point region remains largely rural in character. Agricultural land uses predominate in areas immediately north of the Inner Bay and Big Creek Marsh. Crops are primarily corn, soybeans, vegetables, mixed grains, tobacco and orchards. However, the cottage/tourism/retail sector is probably the most important sector of the economy in Long Point (Wilcox, S. 1996).

In addition to agriculture, five other natural resource uses predominate in the Long Point region: sport and commercial fishing; waterfowl hunting; naturalist activities; and extractive industries such as natural gas and forestry (Wilcox, S. 1996). Extractive industries are seen as having relatively little effect on the core Long Point area, i.e. the peninsula and nearby mainland.

Nature Conservation

In 1866, the Long Point Company, a group of hunters and outdoor enthusiasts purchased most of the land on the point (Skibicki 1993). This was at least partly in reaction to the alarming declines in waterfowl populations in the region and elsewhere in North America due to over-hunting. The Company restricted access to the spit and protected the area for hunting and fishing uses by its members. No doubt this early action on the part of a private group was critical in protecting Long Point from development and subsequent habitat alteration and loss. Without this early conservation effort the Long Point area would not have retained such a high degree of natural habitat.

In 1979, the Long Point Company donated over 3000 hectares of land to the Canadian Wildlife Service (CWS). The land was incorporated into the Long Point National Wildlife Area (LPNWA), which today forms the core of the Long Point World Biosphere Reserve, established in 1986. Due to restrictive covenants placed on the land at the time of transfer, the area must be managed to maintain a wildland state.

The significance of the Long Point area to conservation can partly be noted by the number of protected designations and protected areas in the region. In addition to the LPNWA and designation as a World Biosphere Reserve under UNESCO's Man and Biosphere Program some of the other significant protected areas and designations in the region include (Bird Studies Canadian 2000, Reid et al. 1999, Skibicki 1993):

- Big Creek Marsh National Wildlife Area;
- two provincial parks: Long Point and Turkey Point, both Recreation Class;
- Provincially Significant Wetlands;
- designation under the Convention on Wetlands of International Importance (Ramsar Convention);
- numerous Conservation Areas, including Lee Brown Waterfowl Management Area and Backus Woods;
- Spooky Hollow Sanctuary, a private nature reserve;
- several Areas of Natural and Science Interest;
- International Monarch Butterfly Reserve; and
- Important Bird Area.

Overall, Beazley and Nelson (1996) identified 56 natural areas and sites in the Long Point region that could be considered significant for conservation and sustainable use purposes. Many of the areas are under increasing land use and other stresses. These areas form an interacting system that is poorly understood and until it is better understood, loss or degradation of the individual sites should be avoided.

Biosphere reserve designation should provide an opportunity to integrate a wide range of government conservation initiatives, private stewardship practices and economic activities into a system of planning focused on goals of sustainable development, i.e. protection of the ecological values of the region combined with sustainable economic development. However, the conservation activities in Long Point have frequently been criticized as being too fragmented and uncoordinated to obtain this goal (Skibicki 1993).

Ecological Features and Values

This section will provide a brief introduction to some of the habitats and species of particular significance in the Long Point region. It is intended only as an overview, and the reader is directed to the references for more in-depth discussion.

Abiotic Environment and Processes

Long Point is a dynamic environment. Sedimentary coasts dominate, unlike the rocky coasts predominant in other parts of the Great Lakes, such as Georgian Bay and Lake Superior. Important characteristics of sedimentary coasts found in the Long Point area include high and low bluffs, low graded beaches, dune complexes and a variety of wetlands. Abiotic processes, especially flooding and erosion, are critical for maintaining the beach and dune areas and supporting the evolution and succession of wetland and marsh areas in the Long Point region. Bluffs to the west of Long Point provide the bulk of the sediment deposited at Long Point.

Long Point is thought to have begun to form approximately 7600 years ago (Lawrence 1996, Stenson 1993). As Lake Erie water levels rose, the Paris moraine was reworked and sediments from longshore drift from the east and west of Long Point were deposited in the shallow water environment. This lead to the formation of the Long Point spit. A series of dune ridges was also created, separated by small inlets which were subsequently infilled by sediments and wetland vegetation.

The shoreline in the Long Point region has been modified over time. Protection structures such as seawalls and breakwalls have been constructed. Extensive marina, cottage and other development has taken place. This construction is likely affecting the abiotic environment of Long Point, but the magnitude of these effects is poorly understood (Stenson 1993).

Habitats

Wetlands

Long Point contains the most extensive wetland complex remaining along the Lake Erie shore. Wetland loss in southwestern Ontario has been severe since European settlement of the area, with an estimated 90 percent lost since 1800 (Environment Canada 1991). This makes protecting and maintaining remaining wetland areas of critical importance.

Wetlands in general provide many important economic and ecological functions, and this is certainly true in the Long Point region. The Long Point marshes provide critical habitat for many birds, mammal, fish and invertebrate species and are vital to maintaining biodiversity in the area (Nelson et al. 1996). For example, it has been estimated that approximately 80 percent of fish species in the Great Lakes use nearshore areas for at least part of the year and directly depend on coastal wetlands for some part of their life cycle (Chow-Fraser and Albert 1999).

The importance of the Long Point wetlands is noted in their designation under the Ramsar Convention.

Forests

Forest cover is approximately 18 percent of the watershed area (Beazley and Nelson 1996). There has been a gradual increase in forest cover since the 1950s, due in part to both changes in agricultural practices and reforestation programs.

There are many important forest stands in the Long Point area. Forests in this area are part of the Deciduous or Carolinian Forest, which is of very limited distribution in Canada. The Long Point region has the highest degree of forest cover anywhere within the Carolinian Forest zone, and approximately 10 percent of critical unprotected areas of the Carolinian Forest are located in the region.

Remaining forests and some marsh and savanna areas in the Long Point region have been recognized as forming a basis for a “green framework” or natural areas system. Such systems are now believed to be crucial for long term protection of biodiversity and ecological health.

Species

Before European settlement, Long Point was rich in diversity and number of wildlife. Today the region continues to support significant and diverse assemblages of species that are uncommon in Ontario and Canada, largely supported by the relatively large tracts of Carolinian forest and wetlands remaining in the area (Wilcox, K. 1996).

Birds

Over 300 species of avifauna have been observed in the Long Point region, with over 170 known or suspected of breeding in the area (Cheskey 1996). This represents approximately 80 percent of all species found breeding in southern Ontario. Given these facts, it is no wonder that Cheskey (1996) suggests that Long Point is perhaps the richest and most interesting area for birds in southern Ontario and in all of the Great Lakes basin.

Points of note with regards to birds in the Long Point region are outlined below (Cheskey 1996, Wilcox and Knapton 1996).

- The area has extremely rich and healthy forest bird communities, many of which include long distance migrants.
- High numbers of forest interior species occur.
- High number of species preferring uncommon or restricted habitats occur.
- Extremely rich and productive marsh bird communities are associated with the Big Creek, Long Point and Turkey Point areas.
- Provincially significant populations of species occur at the northern edge of their ranges.
- High concentrations of rare species occur.
- One of the highest winter bird occurrences anywhere in eastern Canada is found in the Long Point area.
- Long Point is an internationally important staging and feeding area in spring and fall for many species, notably large numbers of songbirds as well as waterfowl and shorebirds associated with the extensive marshes of the region. Hundreds of thousands of waterfowl use the marshes during migration, reportedly the highest waterfowl use of any area in the Great Lakes basin.

Other volant species such as bats and butterflies also use Long Point as part of their migration routes, and the Long Point region was designated as an International Monarch Butterfly Reserve in 1995.

Fish

Long Point Bay and the associated wetlands and streams are rich in fish biodiversity. The Bay and marshes provide suitable spawning and nursery habitat for local fish populations as well as fish communities in Lake Erie's eastern and central basin (Craig 1996).

Total fish biomass has remained fairly constant over time, however there has been a dramatic shift in the fish species and fish populations. This shift is mainly due to factors such as fishing effort, environmental modification and exotic species (Craig 1996). In 1990, for example, three exotic species (Rainbow Smelt, White Perch and Carp) accounted for over one-half of the Lake Erie commercial harvest. The implications of this shift in species, away from native and towards exotic species, should be of great concern to all those interested in nature conservation in the region.

Mammals

The Long Point region continues to support a rich diversity of mammals, many of which are uncommon in Ontario and Canada (Wilcox, K. 1996). A number of southern species are common in the Long Point region, but uncommon or vulnerable elsewhere in Canada. These species are typically associated with the large tracts of Carolinian Forest.

A number of species have increased greatly in number since European settlement of the area, notably habitat generalists such as raccoons and White-tailed Deer. Many of these species have the potential to greatly affect plant and other species and features in the region. White-tailed Deer, for example, continue to be of great concern in many protected areas in southern Ontario because of the potential effect of their overgrazing on rare or uncommon floral species. The absence of predator control continues to allow deer and other species to flourish.

Herpetofauna

The Long Point region contains at least 18 species of amphibian, representing 8 genera and 16 reptilian species representing 14 genera (Zammitt 1996). This total includes provincially and nationally rare species that are sometimes found in abundant numbers in Long Point. The Long Point area has not experienced as great a loss in amphibian and reptilian diversity as have other areas in southwestern Ontario in recent decades, likely due to the large tracts of remaining natural habitat and the relatively protected nature of the spit. However, it should not be implied that herpetofauna are not under stress in the Long Point region.

Long Point is also rich in floral diversity, supporting approximately 700 species of vascular plants, with 90 considered rare in Ontario and at least four occurring no where else in Canada (Nelson et al. 1996).

Overall, it is evident that the Long Point region supports a rich variety of species. This species richness is supported by significant wetland and forest habitat. Unfortunately, industrial and economic changes and increases in recreation and tourism are causing increased pressure on the Long Point environment, resulting in changes that are not always well understood (Nelson et al. 1996).

Stresses

Two particularly significant stresses to biodiversity are land use and land cover change, including habitat fragmentation, and changes to water quality. Global climate change is a longer-term threat to the Long Point environment.

Land Use and Land Cover Change

Land Use

Inappropriate or ill-considered development are threatening the Long Point environment. Shoreline protection measures such as seawalls, revetments, breakwalls and other structures are all used in the region, and the percentage of shore that is "protected" has steadily increased over the last few decades as development along the shore has increased (Stenson 1993). Development, including marina, cottage and other recreation facilities has acted to modify, fragment or degrade natural habitats, if not resulted in outright habitat loss.

These changes effect the abiotic environment of Long Point, and modify the abiotic processes, notably processes of sediment erosion and deposition and flooding, that are critical to maintaining habitats such as dunes and wetlands. Abiotic processes are a central, if often overlooked, component of ecosystems and ecosystem planning and management. Conservation over the long term requires fully functioning ecological processes. It is of course important to understand and focus on the biotic elements of an ecosystem in planning and management. However, it is at least as important to understand, protect and where necessary restore or enhance the abiotic processes. Without them, long term conservation efforts are not likely to succeed.

Stenson (1993) suggests that, in terms of abiotic processes, two important concepts should be noted: evolution and geodiversity. Evolution in this regard refers to recognizing and incorporating the dynamic nature of the Long Point landscape into planning, management and decision-making. Geodiversity – variations in the landscape or the abiotic elements of ecosystems – is an important conservation concept. Diversity of abiotic features is often lost during construction as areas are graded or otherwise modified. This loss reduces aesthetic values and reduces the ability of the area to host a variety of species and habitat. The central point is that biodiversity cannot be maintained without geodiversity.

There are other impacts of shoreline change. Wilcox and Knapton (1996) noted that cottage and marina development along the Inner Bay shoreline may result in wetland fragmentation and vegetation removal to create and maintain boat channels. This practice is known to affect waterfowl and food resources. Human efforts at shoreline protection against flooding and erosion are also likely threatening or likely to threaten some species, such as herpetofauna (Zammitt 1996).

Land Cover

Lawrence and Beazley (1994) outline land cover change that took place in the Long Point region from 1955 to 1990. They found that:

- agricultural land cover increased from 53 to 57 percent;
- forest cover increased from 17 to 19 percent;
- wetlands decreased from 22 percent to 15 percent; and

- built up areas (6 percent) and other land cover types (<0.5 percent) remained unchanged.

Most significant among the changes was the one-third loss of wetland cover from 1955 to 1990. Wetland loss was found to be highest along the north Lake Erie shore and around the causeway, and lower on the spit itself. The decline in wetlands is partially attributed to higher Lake Erie water levels, but other important factors include drainage for agriculture and cottage and marina development in the region with associated dredging.

Although forest land cover has increased overall, fragmentation of forest habitat is a concern. Fragmentation and loss of some forested areas occurs for reasons such as: the cumulative impacts of development in natural areas; expansion of agricultural uses into forested areas; and logging (Cheskey 1996). This latter factor is of growing concern, as intensive logging increases on Conservation Authority lands in reaction to drastic reductions in government funding.

Changes in land cover and land use are of grave concern. The impacts of these changes, and the cumulative impacts of ongoing small scale projects are not well understood. It is thought that changes in land cover and land use are in part responsible for declines in bird populations (Cheskey 1996), herpetofauna populations (Zammitt 1996), as well as other species. Land use and land cover changes are modifying the abiotic environment and thus abiotic processes, and affecting habitats and species in ways that are currently poorly understood.

Water Quality

Although the Inner Bay and areas around Long Point have not experienced great declines in water quality, there is reason for concern. In general, it is difficult to determine temporal changes in water quality in the region due to the lack of consistent monitoring. One attempt to determine trends in water quality is documented in Downey et al. (1994). These authors compared water quality studies done in 1966 and 1981 (Berst and McCrimmon 1966, Lerch 1981) with data from the Ontario Ministry of Environment's Drinking Water Surveillance Program. They found that there had been a greater than five-fold increase in nitrate levels between 1979 and 1993. The sources of nitrogen pollution are likely runoff from agricultural lands and leaching from septic systems associated with extensive cottage and recreational development. Their findings should be considered a warning sign of problems to come, and need to be taken seriously.

Work has also been done on the suspended sediment entering Long Point Bay via its major tributary, Big Creek. The sediment is generally enriched with phosphorus, lead, copper, cadmium, zinc and pesticides. The metals and phosphorus are predominantly in bioavailable forms with all being above the lowest effect levels set by water quality standards (Stone and English 1993). The potential adverse effects of this pollution on species and habitats in Long Point require greater study.

Stenson (1996) also noted impacts on water from local land uses. Development and agricultural activities results in soil erosion, resulting in soil flowing into streams. Fertilizers and other agro-chemicals are also introduced to both ground and surface water. Groundwater resources are depleted as water is withdrawn for irrigation and drinking water. These stresses to water resources are likely to increase.

Climate Change

Based on General Circulation Models (GCMs), it seems likely that changes in precipitation and temperature could significantly affect water levels in the Inner Bay (Staple 1996). Lake Erie water levels are expected to drop an average of 1.35 meters over the next fifty years, due to higher summer temperatures, increased evaporation rates and decreased summer precipitation. Lower water levels are likely to affect the wetlands, resulting in their evolution to drier habitats. The vegetation changes would displace or otherwise affect a variety of species notably the waterfowl, herpetofauna and fish that currently rely on the wetlands for at least part of their life cycle.

It must be explicitly noted that impacts from stresses, including those noted above, will affect not only the ecological health of the Long Point region, but also the economic welfare of local people. For example, tourism and recreational activities are of key importance to the local economy. A number of recreational and other economic activities in the Long Point area are dependent on waterfowl and other species and the habitats they require for long term survival. Loss of wetland habitat may result in reduced or lost recreational opportunities, such as sport fishing, hunting and naturalist activities. On the other hand, it is recreational and tourism development, as currently practiced, that are in part threatening these species and habitats, putting a sustainable economic future at risk.

Ecological Linkages

In thinking about critical linkages among the ecological features and values in the Long Point region, several linkages immediately come to mind: water, wetlands and abiotic processes. A number of other potential linkages could be identified, for example birds, fish or other species.

Water

Water directly links may distinct physical aspects of the environment, and links upland areas to transitional zones such as wetlands and finally large water bodies such as the Inner Bay or Lake Erie. In other words, water is a critical linkage between terrestrial, wetland and nearshore water environments in the Long Point region. Water has the ability to great influence many aspects of the Long Point environment, both in an ecological and human sense.

It has become increasingly recognized that what happens in the upper reaches of a watershed greatly influences the ecological well-being of lower reaches in a watershed. Changes in terrestrial land use or land cover are often reflected in the water. Agricultural land uses or residential, commercial or other development can result in increased inputs of soil into streams. This in turn results in increased sedimentation in coastal wetlands and larger water bodies, such as the Long Point Inner Bay or Lake Erie. Agro-chemicals and other pollutants from upstream land uses may also enter water features, including both streams and groundwater. These pollutants are then transported wetland areas and open water bodies, potentially affecting species and habitats downstream.

Excessive withdrawals of groundwater resources in the upper reaches of the watershed could result in reduced discharge to streams and rivers and to wetlands, resulting in degradation or loss of habitat or reduced ability to support some species, for example hydrophilic wetland flora. This in turn could result in evolution of wetland areas to drier habitat types. Climate change may also reduce water quantity levels, further threatening this critical habitat type.

Water-based recreation is important to the economy of the Long Point region, and thus may be affected by changes in water quality and quantity. Change in water quality and quantity may also impact drinking water supply for local communities.

Changes in water supply, both quantity and quality, are indicators of how well we treat the land. Focusing on protecting water quality and quantity in planning, management and decision-making can result in thinking about broader environmental issues, including protecting important habitat areas because of their positive influence on controlling and protecting the water supply. Focusing on water as a ecological linkage has the potential to highlight the integrated nature of ecosystems, as well as the necessity to focus on such linkages for the benefit of both human and non-human communities.

Wetlands

It would be difficult to overstate the importance of the Long Point wetlands. Wetland losses in southwestern Ontario have been severe since European settlement of the area and the Long Point wetland complex is the most extensive one remaining along the Lake Erie shore. We should guard carefully against its loss or degradation.

Many significant species in the Long Point region depend on wetland habitat. Bird, mammal, amphibian, reptile and fish species all rely on the Long Point wetlands for at least part of their life cycle. Many of the species supported by the Long Point wetlands are uncommon or vulnerable outside of the Long Point region. In addition to supporting a wide variety of species, wetlands provide other important ecological services, such as improvement of water quality and protection against changes in water quantity, i.e. flood attenuation.

Loss in either extent or quality of the wetlands has the potential to detrimentally affect many of the important ecological features and values of Long Point. In this sense, they should clearly be considered a linking feature.

Wetlands are often considered transition zones, noting the linkage they provide between terrestrial systems and open water environments. What happens in either environment has the potential to influence the wetland habitat. Degradation in water quality in open water environments, for example the Inner Bay or Lake Erie, can result in degraded water quality in the coastal wetlands. This degraded water quality may influence floral species, for example by promoting the growth of pollution-resistant species. Changes in floral species composition may then impact faunal species growth in the wetland or the ability of the wetland to act as a feeding or staging area for any number of faunal species. The potential of terrestrial land uses to affect wetlands was noted above.

The Long Point wetlands are under stress. Wetland loss continues, as noted by Lawrence and Beazley (1994). Loss and fragmentation resulting from development pressures are directly reducing the extent of wetland habitat. Alterations in the abiotic processes required to maintain wetlands, for example flooding, may also be affecting the Long Point wetlands. The effects of other environmental changes, notably water quality, are not fully understood. Climate change will almost certainly profoundly affect the Long Point wetlands, again in ways we can at best only partly understand at this time.

Abiotic Processes

Abiotic processes, notably sediment erosion and deposition and flooding, are critical to maintaining the Long Point ecosystem. Altering these processes will impact the development and evolution of critical habitats in the Long Point region, notably wetlands, which in turn will impact the species dependent on these habitats. Finally, ecosystem degradation in the Long Point region will affect local economies, which rely heavily on nature-based recreation and tourism.

Changes in the terrestrial environment, for example shoreline protection and development along the coast alter the abiotic environment and processes. These changes alter natural – and critical – hydrologic features of the Long Point environment, notably flooding of nearshore environments and the erosion, transportation and deposition of sediment. Alteration of these processes then affects wetland and other habitats, impacting the species dependent on these ecosystems.

Shoreline protection measures are usually direct attempts to modify abiotic processes, i.e. prevent erosion of bluffs, or are put in place to lessen the impact of processes, such as flooding. Structures constructed to modify or prevent these natural processes do so, sometimes, at the direct sacrifice of natural ecosystems which may themselves have acted to attenuate natural processes. Certainly, these “protection” measures can result in impairment of natural habitat. Flooding, for example, is important in the natural evolution of coastal wetlands. Changes to natural flooding processes will influence the evolution of wetland habitats, with the resulting repercussions to the floral and faunal species which depend wholly or in part on wetlands.

In order for long term conservation and protection of the Long Point ecosystem, attention must be paid to the abiotic processes that are critical to creating and maintaining the system.

Planning and Management

Recognition of Long Point’s exceptional ecological values has resulted in many protected area designations, including World Biosphere Reserve designation. Biosphere reserve designation is intended in part to allow for coordination of planning, management and decision-making in an effort to promote sustainability. In addition, recognition of the importance of single ecological features have resulted in specific planning or management initiatives being introduced. Birds are an excellent example in this regard. The Long Point Bird Observatory has been very active in the region since the 1960s and has been critical in raising awareness and understanding of the birds of the Long Point region. In August 1996, Long Point was recognized as the first globally significant Important Bird Area in Canada. This designation is the latest in a list of designations that have recognized the critical value of habitat in the Long Point area for avifauna, and the need to ensure that both public and private stewardship efforts recognize this and work towards protecting the ecological values associated with the area.

Despite conservation activities over a number of years, the Long Point region is still under stress, most notably from ill-planned and inappropriate development and land use. Skibicki (1993) rated twenty-three targeted and general institutional arrangements in the Long Point region as being of primary significance in efforts towards achieving regional ecological and human economic sustainability. However, he noted, many of these institutional arrangements operated in ways that lacked the broad, regional orientation required to achieve the goals of sustainability. They also lacked coordination.

The critical challenge is to find a way to integrate the many conservation initiatives, government and non-government agencies and groups and stakeholders interested in the Long Point region. These groups and individuals often have different and sometimes conflicting goals, objectives and values, hindering coordinated efforts towards protecting, maintaining and enhancing the ecological features of Long Point, upon which both the natural and human environments depend. The biosphere reserve designation provides a forum in which this cooperative work can take place, however as Skibicki (1993) noted agencies and groups still act independently, creating plans or acting in ways that conflict with the plans or activities of other groups or agencies.

What is truly needed for the Long Point region, and what is perhaps the best way to address planning and management of ecological linkages such as water, wetlands, abiotic processes and others, is effective regional conservation planning. Sportza (1999) provides an overview of the basis and nature of regional conservation planning. In other words, what is needed is broad-visioned, integrated, coordinated, regional- or landscape- scaled, ecosystem planning and management. While elements of such planning are in place, notably the framework offered by biosphere reserve designation, the continued stresses and threats to the Long Point environment require a re-assessment of the planning, management and decision-making approaches used in the region.

There are a growing number of attempts – successful to varying degrees – at regional planning with a strong focus on environmental issues. The Long Point region could learn from the experience of others, as well as become a role model itself for other areas in the Great Lakes Basin and beyond. An excellent example is work done by the British Columbia Commission on Resources and Environment (CORE), which placed strong emphasis on participatory decision-making (Day et al. 1998). Another potential model or instructive tool might be that of ecosystem conservation planning for national parks or the "greater park ecosystem" concept (Nelson et al. 2000). What these models have done is to try to find ways to bring together diverse groups, values, points of view, goals and objectives to integrate them into a common vision for a region. From this common vision, more specific plans and management actions can be developed, each agency or group working independently and within their own mandate or scope of interest, but with the so-called "Big Picture" in mind. The broad plan, agreed upon by all stakeholders working in a participative manner, can and should provide the framework within which individuals and groups plan, manage and make decisions.

This type of planning is not easy. It requires great investments of time and money, patience and flexibility on the part of all participants and critically, the active support of decision makers with the ability – and willingness – to implement agreed upon actions and programs and enforce policies, regulations, programs or whatever measures are decided upon. To truly provide long term protection of the Long Point ecosystem, coordinated, integrated planning is required. Finding the method of undertaking such planning and decision-making that best suits the needs of the Long Point ecosystem and citizens is in itself a challenge that will require time, money and open and on-going communication. The biosphere reserve provides an excellent starting point, one which few other ecologically important areas have. This may provide the needed framework within which to further study and identify critical ecological linkages in the Long Point region, and to begin planning to protect and enhance these linkages, thus providing for long term conservation of the remarkable Long Point ecosystem. This work needs to begin as soon as possible, before further loss and degradation of the Long Point ecosystem takes place.

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Comparative Watershed Study case study

Scientists at the US EPA Mid-Continent Ecology Division-Duluth (National Health and Environmental Effects Research Laboratory, Office of Research and Development) have been implementing a demonstration project in coastal watersheds surrounding the western arm of Lake Superior to assess the utility of watershed classification schemes in monitoring and diagnosis of biological impairment. We are comparing traditional geographically-based classification schemes (Omernik and Gallant 1988, Maxwell et al. 1995) with classification strategies based on hydrologic thresholds, using watershed-scale indicators for those thresholds (Detenbeck et al. 2000). The resulting classification scheme can then be applied as a stratification factor in monitoring designs, to explain differences in reference condition of aquatic systems, as well as intrinsic differences in sensitivity to non-point source stressors and capacity to recover. A secondary goal for this project is to develop diagnostic signatures associated with nonchemical stressors for periphyton, macroinvertebrates, and fish, and link these community level effects with landscape indicators of disturbance. Both goals will support the need for states to move beyond assessing condition of aquatic systems (305b reports) to diagnosing causes of biological impairment as one of the critical steps in the development of 303d lists and total maximum daily loads (TMDL's) and establishment of priorities and targets for watershed restoration (Unified Watershed Assessments).

In the initial demonstration project, we are assessing two hydrologically-based thresholds of impairment, one for watershed storage (5-10%), and one for mature forest coverage (40-60% of watershed in mature forest cover). Selected hydrologic thresholds are related 1) to natural variation or altered levels of watershed storage, defined as the fraction of watershed area covered by lakes and wetlands, and 2) to land-use activities affecting runoff and, thus, the hydrologic regime. The USGS has defined a series of empirical nonlinear equations relating watershed attributes such as watershed area, channel slope, watershed storage, and land-use (% forested, % urbanization or % impervious surface area) to peak flows of given recurrence intervals (Q_2, Q_5,... Q_{100}; Jennings et al. 1993). When peak flows per unit watershed area are plotted as a function of watershed storage, a nonlinear response is shown, with peak flows increasing exponentially as watershed storage decreases below a given threshold. For northwestern Wisconsin and northeastern Minnesota, the critical thresholds appear to be 5-10% watershed storage (Krug et al. 1992, Jacques and Lorenz 1988). A second threshold, in peak snowmelt, related to forest fragmentation from logging or other land-clearing activity, has been predicted to occur after 40-60% of a watershed has been logged within the last 15 years (Verry 1986). This approach could be extended to other regions of the country with other predominant land-uses by identifying critical thresholds for % urbanization or impervious surface area or for agriculture (Detenbeck et al. 2000).

We hypothesize that 1) aquatic community structure and function vary with watershed hydrogeomorphology and watershed-specific stressors due to associated impacts on in-stream habitat and disturbance regimes, 2) watersheds with higher forest fragmentation will have more unpredictable stream flows, increased water temperatures, higher suspended sediment loads, and greater nutrient export, 3) high wetland coverage will mediate effects of forest fragmentation on aquatic community structure and function, sedimentation rates, discharge rates, and nutrient retention, and 4) the sensitivity and/or recovery potential of aquatic communities can be predicted as a function of hydrogeomorphology and patterns in land-use/land-cover.

Two series of comparative watershed studies have been implemented, the first examining condition of second-order streams (Strahler 1964), and the second examining the condition of third-order streams draining into the western arm of Lake Superior. Two different hydrogeomorphic regions were compared, the North Shore Highlands (relatively steep elevation gradient, thin soils, bedrock-dominated) vs. the Lake Superior Clay Plain (thicker, erodible clay soils with lesser elevational gradient). Within each region, watersheds were classified into those with low vs. high watershed storage and, within each storage class, into those with low vs. high mature forest cover. In 1997-1998, 24 second-order stream watersheds were selected to establish a 3-way factorial design. In 1998-1999, third order watersheds in high and low fragmentation classes were selected along gradients of watershed storage within each HGM region to evaluate threshold effects of storage on hydrologic regimes and watershed exports. Endpoints examined included the hydrologic regime (e.g., indicators of stream flashiness), thermal regime, baseflow water quality and sediment and nutrient loadings, habitat structure, and algal, macroinvertebrate, and fish communities.

Diagnostic community- and ecosystem-level indicators under development include % siltation-sensitive diatoms in the periphyton community, and stable-isotope signatures as an indicator of shifts in food webs. In addition, nonparametric multivariate techniques and indicator analysis are being used to determine the sensitivity of fish, macroinvertebrate, and periphyton species and guilds to the different environmental gradients identified (e.g., temperature, flow, habitat structure, nutrients, siltation), so that community-level metrics can be constructed that are diagnostic of individual stressors or suites of co-occuring stressors (Mather 1976, Beals 1984). Ultimately, these metrics could be calculated using the same set of data used to predict biological condition, i.e., for development of indices of biotic integrity (IBI's). Metrics describing flow and thermal regimes are being evaluated for their ability to predict sediment and nutrient loadings (flow metrics; e.g., Richards 1990) and to predict biological community response (flow and thermal regime metrics; e.g., Poff and Ward 1989, Poff and Allan 1993, 1995; Clausen and Biggs 1997; Scheller et al. 1998).

Initial findings are that fish IBI scores and the Qualitative Habitat Evaluation Index (QHEI) scores are lowest within the Lake Superior Clay Plain region, within watersheds with low storage and low mature forest cover. Overall fish IBI scores are significantly higher in low fragmentation class watersheds ($p < 0.001$). Percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in macroinvertebrate communities from kick-net samples are significantly higher in the North Shore Highlands region, and within low forest fragmentation classes for the North Shore region only. Water quality and habitat variables impacted by watershed storage and/or mature forest cover include baseflow and snowmelt phosphorus and nitrogen concentrations and N:P ratios, thermal regimes, turbidity, % fines in sediments, and bank erosion. While baseflow nitrogen and phosphorus concentrations vary significantly across regions, variation within regions is driven mainly by watershed storage for phosphorus vs. mature forest cover for nitrogen.

Aquatic communities responded to different environmental thresholds, with fish community composition driven primarily by temperature gradients and macro-invertebrate and algal communities responding mainly to substrate characteristics and clean sediment impacts. Percent siltation-sensitive diatoms shows promise as an indicator of clean sediment impacts, and is significantly correlated with % fines in the sediments based on visual habitat assessments ($r = 0.76$, $p < 0.05$). Within macroinvertebrate communities, netspinner taxa decrease as a function of % embeddedness of stream sediments. Netspinner insects are vulnerable to high sediment loads in streams, but are not very sensitive to high nutrient loads. Thus netspinners may be a diagnostic indicator of clean sediment problems in streams.

Follow-up studies (2000 - 2001) are currently underway in Great Lakes Superior and Michigan to examine the effects of watershed characteristics on coastal wetland condition. In the Lake Superior assessment, there are three main goals. One is to test fish sampling methods to help refine approaches that will be utilized for sampling during the coastal wetland REMAP study next year in support of the development of fish IBI's.. There is a general lack of data on fish ecology in coastal wetlands in the Great Lakes (Jude and Pappas 1992). There is even less data on the efficacy of different sampling methods for fish in coastal wetlands. Because of previous studies in these habitats, we have a fairly extensive database on methods efficacy and general fish ecology in Great Lakes coastal wetlands. Based on these studies (e.g. Brazner 1997, Brazner et al. 1998), we have identified several methods variations that should be tested before a final decision is made about specific fish sampling methodologies for the REMAP coastal wetland project. These efforts will also be helpful in groundtruthing REMAP study sites for accessibility and special requirements for sampling in 2001 when the fieldwork is scheduled to begin.

A second goal of the Lake Superior assessment is to determine if hydrogeomorphology of coastal wetlands has an important influence on the biotic communities that utilize coastal wetlands in the Great Lakes. Although there is a presumption that coastal wetland hydrogeomorphology influences biotic community structure and function (Maynard and Wilcox 1996, Keough et al. 1999) there is little supporting evidence. The evidence that is available comes from plant studies which suggest that shoreline processes (Geis 1979) and hydrologic fluctuations (Keddy and Reznicek 1986, Keough 1990) affect the structure, succession, and growth form diversity of macrophyte communities associated with Great Lakes coastal wetlands. Since it is well known that community structure of higher trophic levels is influenced by vegetation structure in coastal wetlands (e.g. King and Brazner 1999, Cardinale et al. 1998, Brazner and Beals 1997) it seems likely that community structure and function of these higher trophic levels is also tied to differences in wetland hydrogeomorphology. This issue is important for determining what kind of reference sites should be compared with potentially impacted sites in development of biological indicators and assessment of regional condition.

Our final goal of the Lake Superior assessment is to determine if watershed fragmentation affects the structure or function of biotic communities associated with riverine coastal wetlands. Although watershed fragmentation has been shown to be related to the structure and function of biotic assemblages in streams from Western Lake Superior watersheds through research conducted as part of an earlier phase of this project (Detenbeck et al. 2000), fragmentation effects on biota associated with Great Lakes coastal wetlands have not been quantified. Land use (e.g. forested, agricultural, urban) in the watershed has been found to influence water and sediment quality in Great Lakes marshes in Ontario which helped explain differences in plant communities along a trophic gradient present among those sites (Crosbie and Chow-Fraser 1999). We suspect that a similar influence may be manifest in higher trophic levels in western Lakes Superior coastal wetlands along a fragmentation gradient. We plan to test this idea by examining patterns in fish and zoobenthos assemblages at riverine coastal wetlands selected for differences in fragmentation levels. Sites lowest in mature forest cover (as defined and characterized in the Comparative Watershed Study) will be considered the most fragmented.

The Lake Michigan studies are part of a larger Regional Environmental Monitoring and Assessment Program (R-REMAP) project implemented in collaboration with EPA Region V, the U.S. FWS, USGS, and multiple state cooperators (Simon et al. 1999). The purpose of the R-EMAP project is to develop and assess indices of biotic integrity (IBI's) based on fish community composition (for coastal wetlands in Lakes Superior, Michigan, Huron, and Erie) and IBI's based on macroinvertebrate and macrophyte community composition (Lake Michigan coastal riverine wetlands only). Scientists at the Mid-Continent Ecology Division are testing both response and exposure indicators related to clean sediment and nutrient inputs in support of criteria development for these pollutants. Three approaches to developing a watershed flashiness index and thresholds, based on the cumulative effects of watershed storage, regional precipitation patterns, and land-use intensity, are being assessed in relation to biological, clean sediment, and water quality endpoints measured in the coastal wetlands.

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