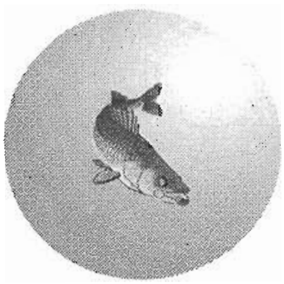
State of the Lakes Ecosystem Conference 1998



BIODIVERSITY INVESTMENT AREAS
Aquatic Ecosystems

Aquatic Biodiversity Investment Areas in the Great Lakes Basin:
Identification and Validation

Draft for discussion at SOLEC 98

Dr. Joseph F. Koonce
Department of Biology, Case Western Reserve University
Cleveland, Ohio

Dr. Charles K. Minns
Great Lakes Laboratory for Fisheries and Aquatic Sciences, Bayfield Institute,
Fisheries and Oceans Canada
Burlington, Ontario

Dr. Heather A. Morrison
Aqualink
Toronto, Ontario

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Internet web-site: http://129.22.156.152/ABIA/index.htm

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Notice to Readers

This paper on Biodiversity Investment Areas is one of three such papers that were prepared for discussion at SOLEC 98. The idea of Biodiversity Investment Areas originated at SOLEC 96 for the Nearshore Terrestrial Ecosystem. This work has continued and been expanded to include Aquatic Ecosystems and Coastal Wetland Ecosystems. The authors of these papers have drawn information from many experts.

Participants are encouraged to review this document prior to SOLEC and provide comments, specific information and references for use in preparing the final post-conference versions of the papers.

Executive Summary

Here, we report on initial efforts to identify and validate candidate aquatic biodiversity investment areas (ABIAs) across the Great Lakes Basin Ecosystems. The ABIA concept is linked to its terrestrial shorelands counterpart, Lands by the Lakes, reported at SOLEC'96 and placed in context with other national and international biodiversity initiatives. The working definition of an ABIA used in this study is: **a specific location or area within a larger ecosystem that is especially productive, supports exceptionally high biodiversity and/or endemism and contributes significantly to the integrity of the whole ecosystem.**

A conceptual framework is presented as the basis for developing scientifically defensible methods for identifying and validating ABIAs. The framework is focused on three dimensions where the three main axes represent biodiversity, spatial units, and habitat features in discrete elements. Paired intersections of the axes represent the distribution of biodiversity (biodiversity and spatial units), the characterization of spatial units, or locations, by the overlaying of many habitat features (spatial units by habitat features), and the niches of individual species and life stages (biodiversity by habitat features). In this preliminary assessment of ABIAs, attention has been concentrated on freshwater fishes.

To augment the implementation of the conceptual framework, a survey of Great Lakes experts was undertaken to establish a preliminary list of candidate ABIAs. So far, the candidate ABIAs provide broad geographical coverage across the basin and many types of spatial unit have been included. The survey approach has many subjective elements resulting from the varying abilities and experience of the experts consulted, the uneven distribution of prior observations and assessment, and the lack of quantifiable criteria for identification. This list of candidates will be compared with the areas identified via the application of scientific models based on the conceptual framework.

The methodology for a quantitative approach to the identification of ABIAs, Habitat Supply Analysis (HSA), is described. This approach is being implemented with the aim of providing a complete assessment for fish ABIAs in the Lake Erie Basin ecosystem (lake, tributaries, and connecting channels) at SOLEC 2000. Meanwhile aspects of the approach are illustrated with results from prototype studies.

The conceptual framework and the components of the habitat supply methodology are used to formulate a comprehensive scheme of status indicators for ABIAs. ABIAs can be classified according to their class (healthy, damaged, lost, and missing), relative level of potential importance as a biodiversity investment areas (low, medium, and high), and their current status (as a percentage) derived from a composite assessment of the many habitat features characterizing the spatial units making up an ABIA. The ABIA classes are matched by ABIA management strategies: healthy – conservation, damaged – restoration, lost – creation, and missing – enhancement. The missing class represents new opportunities to enhance, reproduce, and connect existing ABIAs in overall efforts to restore the integrity of Great Lakes Basin ecosystems.

The next steps toward the creation of a comprehensive ABIA system are outlined.

1. Introduction

Identification of Biodiversity Investment Areas has become a preferred approach to conservation of biodiversity. In contrast to a species-by-species approach, focus on geographical areas provides conservation planning with a way of protecting threatened habitats, communities, and ecological processes on which a wide range of species depend. Strategic identification and protection of a fundamental set of Biodiversity Investment Areas thus results in the preservation of both known and unknown endangered or rare species and genetic diversity within species.

The Nature Conservancy (TNC, 1994) proposed the use of Natural Heritage programs to identify critical areas for maintenance of biodiversity in the Great Lakes Region. This approach was implicitly hierarchical and promoted the view that understanding and managing threats to regions of biodiversity required assessment of essential ecological systems that sustained biodiversity resources. This concept of identifying regions of high biodiversity was applied to terrestrial ecosystems within the Great Lakes basin (Reid and Holland, 1996). Regions of high biodiversity were classified using a landscape-scale analysis of ecologically significant bioregions and constituent ecosystems. Recently, The Nature Conservancy has attempted to consolidate this landscape-scale approach with hierarchical aquatic ecosystem classification for protection of aquatic biodiversity (Lammert *et al.* 1997). The proposed classification systems rely on nested spatial hierarchies, which relate climate influenced ecological provinces to large-scale biological and ecological patterns. Within an ecological province, geology and landforms entrain zoogeography and aquatic ecosystem patterns. In practice, this classification system depends on well-characterized plant communities to demarcate ecoregional provinces. Although aquatic ecosystems are climate and landscape influenced, their ecosystems are dominated by higher frequency dynamic processes. As Steele (1974) suggests, animals in aquatic ecosystems are the analog for plants in terrestrial ecosystems in terms of persistent biomass structure. Unlike plants, however, most aquatic animals are mobile, and the regulatory structures of aquatic ecosystems become inextricably linked to life-cycle ambits of dominant animal species. Consequently, a hierarchical classification of ecoregional provinces, based solely on landscape features, may prove too static to capture the important processes that regulate biodiversity resources in large-scale aquatic ecosystems such as the Great Lakes.

The basic challenge in developing a workable ABIA framework for aquatic ecosystems is to capture both static and dynamic regulatory components. Because fish biomass constitutes over half of the standing biomass of most lake ecosystems (cf. Kitchell *et al.* 1979), the approach we propose here is based on the relation of habitat structure to fish diversity and production. From the level of microhabitat description, this approach is quite compatible to landscape approaches (e.g. Lammert *et al.* 1997; Seelbach *et al.* 1997). It differs, however, in that it provides a biological connection of microhabitat structure to the regulation of ecosystem structure and function through the utilization of these habitat structures by fish throughout their life cycles.

1.1 Background

The importance of preserving the earth's biological diversity (biodiversity) was formally recognized in the Convention on Biological Diversity at the United Nations Conference on Environment and Development (UNCED) in 1992. Canada and the United States of America were among 138 countries that ratified the convention recognizing the importance of biological diversity to humanity's economic and social development. Biodiversity refers to the variety of organisms and the diversity of physical environments in which they occur and is recognized at genetic, species, ecosystem and sometimes landscape levels of organization (U.S. Congress 1987, Noss, 1990). Preserving biological diversity is important because it:

- Provides opportunities for sustainable economic development
- Nurtures human welfare, and
- Enables the ecosystems to adapt to change

and for:

- The aesthetic values of natural ecosystems
- The contribution of land- and water-scapes to the emotional and spiritual well-being of today's highly urbanized human populations
- The cultural identity of many indigenous peoples
- The ethical reason that the earth supports many other life forms that warrant our respect, whether or not they are of benefit to humans (EPA, 1997).

Preserving and restoring habitats have been identified as the best strategies for preserving biodiversity (Arico, 1995; Gray, 1997). In 1996, SOLEC oversaw the designation of **Biodiversity Investment Areas (BIAs)** (See web-site 1.1). in the nearshore terrestrial environment of the Great Lakes. These **BIAs** were defined as clusters of places, called ecoregions, that have exceptional biodiversity value. Biodiversity value was assigned to an ecoregion based on characteristic shoreline types, significance of natural communities, existing representation in parks/protected areas, presence of a priority unprotected feature, land use, trend in shoreline health and, health of associated ecological communities. The purpose of identifying these areas was to draw attention to those nearshore terrestrial sections of shoreline with the greatest concentrations of biodiversity values. The United States and Canada, through the Binational process, decided to expand this effort to identifying similar areas for nearshore, offshore, tributary and coastal wetland environments in the Great Lakes Basin for SOLEC 1998.

1.2 Objectives and Approach

The objective of this study was to identify and, eventually, provide a scientifically defensible basis for the selection of, Aquatic Biodiversity Investment Areas (**ABIAs**) in the Great Lakes. An ABIA is defined as **a specific location or area within a larger ecosystem that is especially productive, supports exceptionally high biodiversity and/or endemism and contributes significantly to the integrity of the whole ecosystem**. These areas can be large (e.g.. a specific tributary and its receiving waters or a whole lake basin) or small (e.g. a coastal wetland, an offshore reef, an embayment, or a segment of shoreline). This definition is similar to but does not completely overlap that used for 'biodiversity hotspots' (Reid 1998). Hotspots are areas with high biodiversity and/or high incidence of endemics or rare species. The ABIA definition reaches beyond the idea of hotspots to encompass consideration of centres of high levels of natural, self-sustaining productivity and ecological integrity of ecosystems as envisaged in the successive versions of the Canada-U.S. Great Lakes Water Quality Agreement.
Fish biodiversity was chosen as the initial indicator of overall biodiversity for the assessment of ABIAs in the Great Lakes. Fish communities are well known to be excellent indicators of overall ecosystem integrity and health (Lyons *et al.*, 1995). Furthermore, preserving fish biodiversity is compatible with conservation of individual endangered species and populations (Lyons *et al.*, 1995). There is also evidence that high biodiversity areas for one taxonomic group are similar for other groups (Reid 1998). This study of ABIAs in the Great Lakes Basin was developed in three phases. In the first phase, a conceptual, and methodological, framework was developed as a basis for placing the ABIA idea into an

appropriate ecological and scientific context (Section 2 below). In the second phase, a survey approach was adopted as a means of identifying ABIAs. This survey began in the summer of 1998 and is regarded as a short-term strategy for designating ABIAs. Progress on the survey is reported in this manuscript (Section 3 below). In the third phase, a scientifically defensible method of validating the identification of ABIAs is described and preliminary indication of its potential to accurately identify these areas is reported. It is regarded as a long-term strategy for identifying ABIAs (Section 4 below). In Section 5, the strength and weaknesses, and advantages and disadvantages of the different identification strategies are assessed along with the operational status of the ABIA concept. The report concludes with a set of recommendations for the future.

1.3 Context

This and similar efforts in SOLEC 1998 to identify and designate biodiversity investment areas (BIAs) parallel and complement other ecosystem management efforts in the Great Lakes Basin and beyond.

These related efforts include the overarching concepts of the Ecosystem Approach and their practical implementation in the Remedial Action Plans (RAPs) for designated Areas of Concern (AOCs) and Lakewide Management Plans (LaMPs) to be developed for each Great Lake under the terms of successive revisions of the Great Lakes Water Quality Agreement. The scope of that agreement has been progressively expanded from a focus on water quality issues to the widest consideration of ecosystem health throughout the basin, including the lands, the waters, the air, the peoples, the economic activities, etc. The BIA efforts complement the Ecosystem Approach in recognizing that conservation and restoration of biodiversity requires the conservation, restoration, and, where necessary because of past indifference or neglect, creation of habitats and ecosystems.

The Great Lakes Fishery Convention Act (1955) and the Strategic Great Lakes Fishery Management Plan (SGLFMP, 1980 And revised 1997) recognize the important role of fishery and other agencies in management and conservation of fisheries, fish productivity, and the ecosystems supporting them. Part of SGLFMP commits the signatory agencies to the development of complementary sets of fish community and environmental objectives for each Great Lake. In the recent revision of SGLFMP, the agencies recognized that those objectives have to be developed in the context of ecosystem management. This study of ABIAs, focused on fish biodiversity, is based on concepts consistent with the goals of the SGLFMP objective setting.

Beyond the Great Lakes Basin, the 1996 reauthorization of the Magnuson Fishery Conservation and Management Act, now known as the Magnuson-Stevens Act, with respect to federally managed marine fish stocks in the United States required that 'essential' habitats for these stocks be identified as a major step toward increasing the management of habitat as a requisite component of stock management. The National Marine Fisheries Service, U.S. Department of Commerce, is responsible for completing essential habitat plans. These activities, that bring stock and habitat management closer together, parallel the ABIA assessment process. Similarly in Canada, the 1986 Policy for the Management of Fish Habitat, while lacking a clear mandate for the conservation of fish biodiversity per se, directs agencies to develop area fish habitat management plans as a basis for managing future threats from development activities and for ensuring that the requisite natural, self-sustaining productivity of habitats supporting fish production and harvests be maintained.

2. Conceptual Framework

As the arenas of ecosystem management are often made more complicated through the use of terms such as biodiversity, integrity, health, *even* ecosystem, etc., whose meanings or interpretations are often contentious, this section presents an attempt to ground the BIA, and particularly the ABIA, ideas on current ecological science, especially aquatic ecosystem science.

2.1 For Biodiversity Investment Areas in the Great Lakes Basin

Biodiversity Investment Areas (BIA) are geographical regions rich in critical habitat for a number of species. Reid and Holland (1996) identified 19 BIAs representing important large core areas of shoreline habitat in the Great Lakes region. The ecoregions represented by these BIAs have characteristic sets of climate and physical features that develop unique assemblages of plants and animals. For shoreline BIAs, plant communities are important indicators of status and serve as benchmarks for restoration. Extending the BIA concept into lakes requires a change of indicators. Because watershed processes influence the structure of aquatic communities, some correspondence between identified shoreline BIAs and Aquatic Biodiversity Investment Areas (ABIAs) is bound to occur. However, plants are much less important regulators of community structure in aquatic ecosystems, and physical and chemical factors are correspondingly more important determinants of local biodiversity. The central challenge of identifying ABIAs within the Great Lakes is thus finding a set of criteria that demarcate habitat structures that are important to maintenance of lake-wide biodiversity and that regulate structure and productivity of lake ecosystems.

2.2 For Fish Biodiversity in the Great Lakes Basin

Like plants in terrestrial systems, animal communities provide persistent structure for aquatic ecosystems. One way to differentiate ABIAs is to evaluate habitat through effects on fish abundance and distribution. Figure 2.1 represents a conceptual framework with which to organize identifying characteristics of ABIA sites. The framework consists of three primary axes: Spatial Units (or Locations), i.e., landscape features that together comprise an ABIA; Habitat Attributes, i.e., qualities that describe these spatial units such as water chemistry, temperature, depth, substrate type, etc.; and Fish Species by Life Stage. All three axes are categorical. Intersection cells represent the suitability of a particular Spatial Unit within a specific ABIA for a particular life history stage of a single species of fish. Projections onto planes of the axes are integrated summaries of Habitat Attributes. An ABIA is thus defined as a set of specific Spatial Units with their associated Habitat Attributes. The intersection of the Fish Species/Life Stage and Spatial Unit axes indicate the fish biodiversity supported by that ABIA, and the intersection of each Fish Species/Life Stage with Habitat Attribute axes represents the niche space.

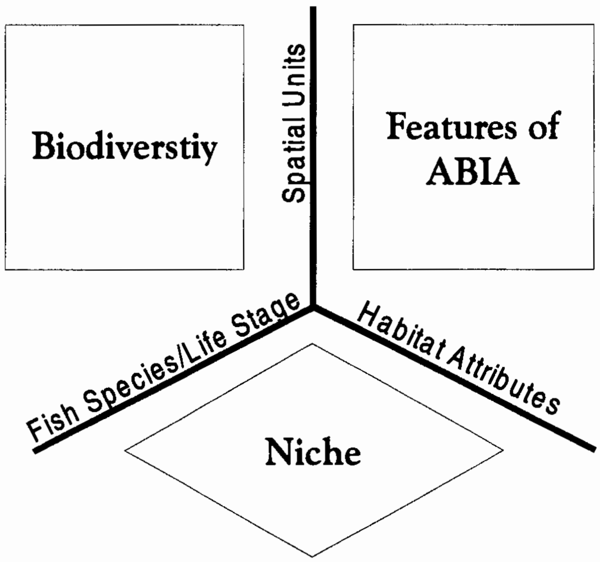
An advantage of the ABIA framework in Figure 2.1 is its reliance on readily discernable axis components. Spatial Units are specific geographical features such as tributaries, embayments, beach littoral zones, wetland littoral zones, pelagic zones, submerged reefs, and profundal regions that together comprise an ABIA. Each Spatial Unit may have subcategories but identification by location, and hierarchical organization, limits category overlap. Furthermore, no two ABIAs will be the same. ABIAs may have the same types of Spatial Units (ex. beach and embayment) but the Habitat Attributes that describe these Spatial Units will be unique to a geographical location and hence an ABIA. Selection of Habitat Attributes, for use in the framework, depends on relevance to fish abundance and distribution.

These attributes will include a range of physical, chemical, and biological characteristics, but the attributes chosen must allow consideration of current, potential, and desired state of the ABIA. Assessment of ABIAs can be conducted through an aggregate consideration of the habitat requirements of all fish species and life stages and methodology to enable this approach will be outlined in section 4 below.

More focused assessments of economically important, rare and endangered species or invading species is also feasible, especially where more detailed knowledge of life stage habitat requirements (niche) is available. Such analyses will not be described in this report but such assessments are under development and will be reported later. Those assessments will allow for a more explicit consideration of the spatial and temporal interconnections and interactions between locations serving different life stages of particular species. The framework provides the basis for tracking habitat constraints throughout the life cycle of a species. Thus locations that serve as corridors connecting essential habitats for consecutive life stage may in a static analysis not appear to be critical or limiting. However, if the connection is broken or disrupted, the value of the adjacent ABIAs may be diminished or lost.

The use of fish abundance and distribution data to identify ABIAs and to indicate status of in-lake habitat is conceptually appealing and more scientifically defensible than approaches that rely too heavily on intuition. Although habitat constraints are only one of several factors that regulate aquatic community structure, a growing body of evidence suggests that availability of habitat can have important effects on both biodiversity and relative abundance of economically important fish. Because of their ability to exert a "top-down" control on aquatic ecosystems, species composition and abundance of fish influence the diversity and structure of other species. For example, excessive abundance of detritivorous species, like Carp, can have a deleterious effect on littoral aquatic vegetation. Through effects on reproduction and survival of early life history stages and through effects on growth and survival of juvenile and adult fish, habitat limitations have the potential to limit the productive capacity of aquatic ecosystems, their ability to respond to invasion of exotic species, and their overall stability. The framework in Figure 2.1 thus lends itself to diagnostic analysis of factors contributing to loss of fish productivity as well as restoration analyses that would indicate levels of habitat availability that would provide various desired levels of abundance and distribution of fish.

Figure 2.1. Conceptual framework for the identification and validation of aquatic biodiversity investment areas (ABIAs), linking biodiversity, habitat attributes, and spatial units.



3. Identification of Candidate Aquatic Biodiversity Investment Areas (ABIAs)

A mail-out questionnaire was the first approach used to identify Aquatic Biodiversity Investment Areas (ABIAs). The following sections describe this approach and the results obtained up to the time of writing.

3.1 Survey Methodology

Seven hundred experts in Great Lakes ecology from Canada and the United States were identified using the SOLEC mailing list database. A questionnaire (Appendix 1) was prepared and mailed to those experts. Recipients were also asked to copy and further distribute the questionnaire to other experts in their organization or group, experts who may not have been included in the original mailing list.
The questionnaire required an ABIA nomination, a detailed description of the site and, attributes of the site that made it a good candidate for an ABIA. Recipients were asked to complete a separate questionnaire for each nomination. An ABIA was defined as a specific location, or area within a larger ecosystem, that is especially productive, supports exceptionally high biodiversity and/or endemism and contributes significantly to the integrity of the whole ecosystem. The questionnaire required the nominator to:

- Identify the candidate as specifically as possible
- Indicate its general position in a lake or connecting channel basin
- Describe the main spatial units using elements in a generic classification scheme, supplemented with commentary where needed
- Select up to 3 items from a list of possible reasons for the candidacy
- Indicate at the life stage, species and community level the target biodiversity elements
- Add any addition comments or explanation

Most respondents completed the check-off portions of the questionnaire and many provided commentary information, often supplemented with other printed material. The results from the questionnaires were compiled in a GIS compatible database and mapped using ArcView® application by ESRI Corporation. Geographical coordinates for candidate sites were obtained where available from two web-sites (1.2 and 1.2). Otherwise, coordinates were read from large-scale paper maps.

3.2 Survey Results

To date, 70 sites have been nominated as ABIAs by 60 experts (Appendix 2 – Detailed Summary of ABIA Survey Responses). Thus, the response rate at the time of reporting was less than 10 percent, a rate considered typical for mail-out questionnaires.

The sites are distributed throughout the Great Lakes Basin (Figure 3.1). Most of the sites (87%) are in the lakes compared to the connecting rivers and most sites are in the upper lakes (Figure 3.2).

Most of the sites were selected because they exhibit a number of important attributes. The majority of sites were indicated to support 'high biodiversity' (57%), are 'very productive' (56%) and are 'critical for economically important species' (41%) (Figure 3.3). The next most frequently selected attributes were 'rare habitat features' and 'critical for rare species'.

The majority of sites were characterized by more than one location feature (Appendix 2). The most common location features, characterizing the sites, were 'wetland' (46%), 'tributary' (44%) and/or 'offshore reef' (36%) (Figure 3.4). 'Shorelands', 'nearshore reefs', and 'islands' were the next most frequently selected features.

To date, 12 of the 70 ABIA nominations are located within Areas of Concern (AOCs) designated by the International Joint Commission (Table 3.1).

3.3 Evaluation

Questionnaires, completed by experts, provided valuable information about the location, characteristics and attributes, and significance of potential ABIAs. Although expert nominations can provide supporting evidence for validating ABIA selection models, used explicitly, they do not provide scientifically robust results because of several methodological shortcomings. These shortcomings include:

- Low response rate of experts to the request for ABIA nominations (<10%)
- Uneven distribution of experts throughout the Great Lakes resulting in a biased geographical distribution of ABIAs
- The competence of the experts to identify ABIAs cannot be assessed or compared.

Other shortcomings arise because some areas have been studied more intensively than others. This discrepancy increases the likelihood that intensively studied sites will be nominated more frequently than lesser-studied areas. For example, the AOCs represent a small proportion of the total area of the Great Lakes Basin but 17 percent of ABIAs were located in AOCs. Also, the constant flux in the pool of Great Lakes experts results in a loss of 'institutional memory' of sites that may have been studied in the past but that are no longer being studied. This may also affect the likelihood of a site being nominated. Furthermore, not every site that is nominated by experts would be considered a good ABIA candidate. An example of this last point, is the nomination of NIPSCO Dean Mitchell Generating Station discharge outlet in Illinois as an ABIA. The warm water from this discharge outlet attracts a number of fish species but the site itself is not characterized by habitat features that support sustainable aquatic biodiversity. Some of the shortcomings might be addressed by amending the questionnaire to gather additional data. However, the shortcomings of the expert nomination process for selection of ABIAs, highlight the need for the development of a scientifically defensible approach.

Table 3.1. Tabulation of ABIAs associated with designated Great Lakes' Areas of Concern.

Site #	Site Name	Watershed	Location Features	Attributes	Comments about Site	Comments about Attributes of Site	Experts
68	Humbug Marsh	Detroit River	Tributary, Wetland	High Biodiversity, High Productivity, Critical for Rare Species, Critical for Economically Important Species, Critical for Endangered Species, Rare Habitat Features, High Connectivity	Last remnant Great Lakes coastal marsh on the 32-mile Michigan shoreline of the Detroit River.	Migration route for the 117 species of fish that inhabit the Great Lakes; for the 27 species of waterfowl that frequent Michigan's coastal wetlands; the more than 17 species of raptors, including eagles, hawks, and falcons; the more than 48 species of non-raptors, including loons, warblers, neotropical songbirds, cranes, and cattle egrets, and numerous species of butterflies that migrate annually from Canada to the southern United States and South America.	Dr. Bruce Manny (U.S. Geological Service)
54	Maumee River, Maumee Bay and coastal shorelands	Erie	Tributary, Embayment, Shorelands	Critical for Economically Important Species		Reproductive habitats for the various walleye life stages are linked by physical processes and function as a unit. These habitats are critical/essential for walleye reproduction and they exist no where else in space or time for this stock.	Mr. David Davies (Ohio Division of Wildlife)
4	Presque Isle Bay and Associated Wetlands	Erie	Wetlands, Embayment, Beach	High Biodiversity, Critical for Rare Species, Critical for Endangered Species, High Habitat Diversity, Rare Habitat Features	Sandspit arcs towards mainland to form large, shallow embayment with aquatic plant beds, emergent marsh, shallows, beaches and mussel beds.	This site supports rare species including the bowfin, spotted gar, Iowa darter, lake sturgeon, eastern sand darter and Great Lakes muskellunge. Furthermore, this site supports approximately 20 species of freshwater mussels and several rare fish species; productivity and species diversity are high.	Mr. Roger Kenyon (Pennsylvania Fish and Boat Commission); Mr. Charles Bier (Western Pennsylvania Conservancy)
63	St. Clair River Delta/Lake St Clair	Erie	Wetlands, Embayment, Shorelands, Islands	High Biodiversity, High Productivity, Rare Habitat Features, Critical for Rare Species, High Connectivity	Submergent and emergent macrophytes. Shallow, warm and productive waters. Migratory route for valuable fish populations from Lakes Erie and Huron.	One of the last remaining stretches of natural shoreline, spawning and nursery ground for numerous fish species. Most diverse native plant, vertebrate, and invertebrate communities in Great Lakes.	Dr. Tim Johnson (Ontario Ministry of Natural Resources); Dr. Heather Morrison (Aqualink); Mr. Robert Haas (Michigan Department of Natural Resources)
39	Saginaw Bay	Huron	Tributary, Wetlands, Nearshore Reef, Embayment	High Biodiversity, High Productivity, High Habitat Diversity, Critical for Economically Important Species	Saginaw Bay offers a huge variety of habitat types such as very large stands of emergent grass wetlands and nearshore rocky bottom that are highly productive and which support a rich and diverse flora and fauna.	Saginaw Bay supports a rich flora and fauna through high rates of primary productivity and very protected shallow waters along with emergent grasses. Saginaw Bay and tributaries support extremely valuable sport fisheries for a variety of species, principally yellow perch and a recovering walleye population. The bay also supports a commercial fishery for whitefish, yellow perch and other species.	Dr. Dave Fielder (Michigan Department of Natural Resources); Dr. Russell Moll (Michigan Sea Grant); Mr. James Baker (Michigan Department of Natural Resources)

Table 3.1. continued

Site #	Site Name	Watershed	Location Features	Attributes	Comments about Site	Comments about Attributes of Site	Experts
31	Thunder Bay	Huron	Tributary, Wetlands, Nearshore Reef, Embayment, Shorelands, Pelagic	Rare Habitat Features, High Biodiversity, Rare Habitat Features	Some of the last remaining Great Lakes shoreline wetland habitat. Area has many shipwrecks that provide habitat for fish.	This site should be considered a marine sanctuary.	Dr. Dave Fielder (Michigan Department of Natural Resources); Mr. Alfred Beeton (Great Lakes Research Laboratory)
43	Klydel Wetland	Niagara River	Wetlands	High Biodiversity, High Productivity, Rare Habitat Features	This wetland was originally 102 acres but only 60-70 acres remain. Desperately needs protection from illegal development and threatened development.	Endangered wetland in urban setting. Wetland is being used as a nature area for environmental education on the 9.3 acres that is owned by North Tonawanda School District. We're trying to save the rest.	Mrs. Elizabeth Kaszubski (Citizens for a Green North Tonawanda)
33	Cootes Paradise and Hamilton Harbor	Ontario	Wetlands, Embayment	High Biodiversity, High Productivity, High Connectivity	Undergoing restoration. Surrounded by urbanization and upstream agricultural stresses.	Critical part of a sequence of connected streams, wetland, bay, open lake, shore areas and open lake pelagic.	Dr. Charles Minns (Fisheries and Oceans Canada)
8	St. Lawrence River	St. Lawrence	Wetlands, Embayment, Shorelands	High Productivity, Critical for Economically Important Species, Rare Habitat Features	Migratory route for economic important species such as the american eel. It is also growth habitat for eel.	Main nursery and migratory habitat for eels that are the basis of a commercial fishery - also member of the predatory fish community.	Dr. Peter Hodson (Queen's University)
73	St. Marys River	St. Marys	Wetlands, Nearshore Reef, Islands	High Biodiversity, High Habitat Diversity, High Connectivity	The St. Marys offers not only a variety of habitat but also some unique environmental conditions.	The river offers a blend of many habitat types.	Dr. Dave Fielder (Michigan Department Natural Resources)
3	Nipigon River/ Nipigon Bay	Superior	Tributary, Embayment	High Biodiversity, Critical for Rare Species, Critical for Economically Important Species		River has a high biodiversity of fish species and a remnant population of brook trout. This is the last refuge for coaster brook trout. It also supports a recovering lake sturgeon and walleye population. It is the largest tributary to Lake Superior.	Mr. Bob Thomson (Ontario Ministry of Natural Resources); Mr. Ed Iwachewski (Ontario Ministry of Natural Resources)
67	St. Louis River	Superior	Tributary, Wetlands, Embayment	High Productivity, Critical for Rare Species, Critical for Endangered Species	Large commercial harbor; area of concern; high value habitat; largest US tributary to Lake Superior.	Common tern nesting site; walleye spawning area for western Lake Superior; sturgeon restoration; significant remaining wetlands.	Ms. Karen Plass (St. Louis River Citizens Action Community)

Figure 3.1. A map of the Great Lakes and their drainage basins showing the distribution of candidate ABIAs identified by experts in survey responses.

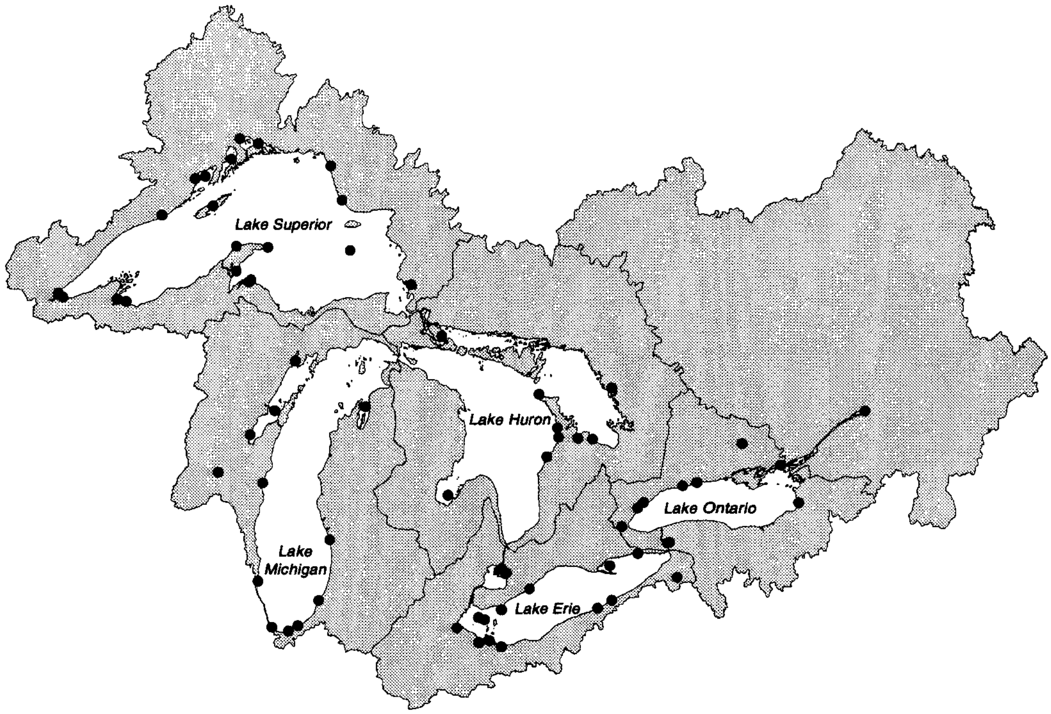


Figure 3.2. The percentage frequency distribution of candidate ABIAs among the Great Lakes and connecting channels.

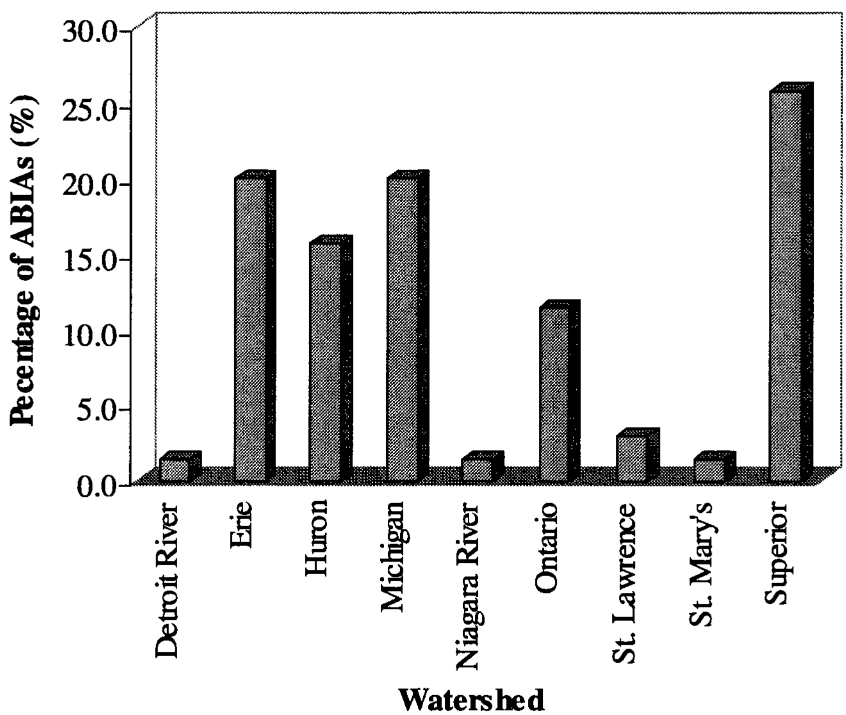


Figure 3.3. The percentage frequency of occurrence of various selection criteria among candidate ABIAs.

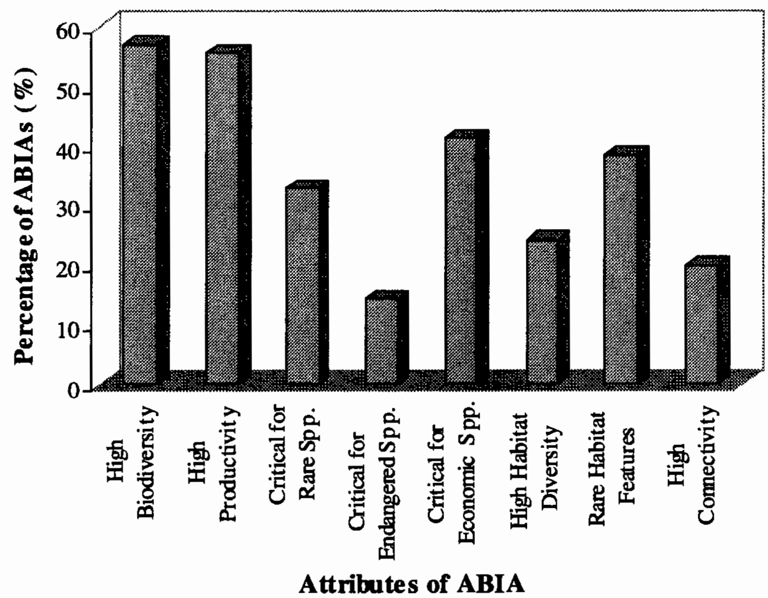
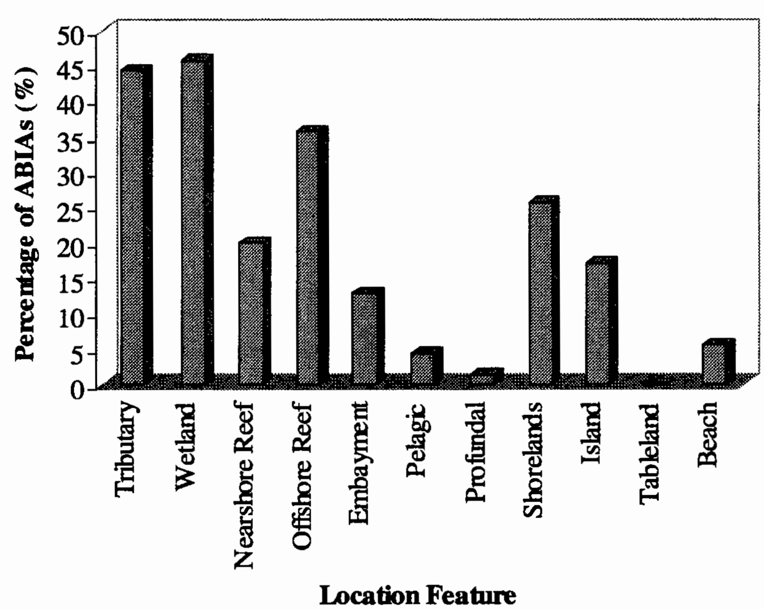


Figure 3.4. The percentage frequency of various spatial unit types among the candidate ABIAs.



4. Validation of Candidate ABIAs Using Habitat Supply Analysis

The conceptual framework (Section 2 above) provided the template for a method of identifying ABIAs for all biodiversity and, particularly, for fish biodiversity. In this section, an approach to translating the conceptual framework into an operational tool is described. Prototype results illustrate what might be expected when a habitat supply analysis is completed for the Lake Erie Basin. A science-based, reproducible methodology will:

- Decrease reliance on a limited and changeable pool of experts able to recognize ABIAs
- Allow the identification of ABIAs in more remote and less studied areas of the Great Lakes, and
- Contribute to the development of more extensive mapping of BIAs in the Great Lakes basin and beyond
- Once ABIAs are identified, efforts can be taken to conserve and/or restore these areas as needed to attain overall ecosystem management goals and objectives.

4.1 Habitat Supply Analysis

Habitat Supply Analysis (HSA) is a data synthesis and integration methodology that enables implementation and testing of the conceptual framework described earlier. The three primary surfaces, defined by the axes of the conceptual matrix (Figure 2.1), may be visualized as elements in an equation that predicts locations of high biodiversity from the product of fish habitat suitability models and the characterization of locations using a range of habitat attributes. The primary objective of the HSA portion of this project is to test the powers of fish species/life stage-habitat attribute suitability models. These models are used, in combination with GIS-based representations of the Habitat Attributes of each Spatial Unit, to predict observed patterns of Fish Species/Life stage in each Spatial Unit. The predicted patterns of Fish Species/Life stage in each Spatial Unit represent the biodiversity at an ABIA.

Application of this HSA approach, to validating the identification of ABIAs, does not preclude other methodologies for identifying ABIAs or other applications of HSA. Indeed HSA, as applied to fish, is envisioned as the central resource for information and assessment in the development and implementation of Area Fish Habitat Management Plans (AFHMPs). Such plans can provide:

- A habitat inventory in a GIS-based information system with analytical capabilities.
- An overview and context for planning biodiversity and habitat conservation and restoration priorities.
- A means of identifying key habitat features and significant locations.
- A direct link to fishery resource management wherein habitat objectives are marshalled in support of fisheries objectives.
- A solid guide for development activities and regulatory actions by conservation authorities and local governments. If you have a colour-coded map, you can get that consideration built into local planning documents and guidelines.
- A context in which site-specific activities can be assessed.

The current project, to validate the ABIAs identified by experts, is consistent with the wider applicability of AFHMPs.

The present HSA approach is consistent with, and derives elements and concepts from, a number of previous efforts to address conservation and protection of natural ecosystems. Previous efforts include the HEP-HSI approach of USFWS (USFWS 1981, Terrell *et al.* 1982) and GAP analysis (Scott *et al.*, 1993)

4.2 Components of Habitat Supply Analysis for ABIAs

There are four main components in the application of HSA:
1) Fish species/Life stage-Habitat Attribute Suitability Modelling,
2) Habitat Attribute-Spatial Unit Mapping,
3) Spatial Unit-Fish species/Life stage Suitability Mapping (Biodiversity Mapping), and
4) Comparison of Biodiversity Maps with the Distribution of ABIAs.

Implementation of these steps is planned for both a generic assessment of fish species biodiversity and a specific assessment of the suitability of habitat to fish species of special interest. The sequence described below is given in detail for the generic assemblage assessment. This same sequence would be followed for a species level assessment.

4.2.1 Fish species/Life stage-Habitat Attribute Suitability Modelling

The approach to habitat attribute suitability index modelling is based on the Defensible Methods approach developed by Minns *et al.* (1996, 1997, 1998a,b). At present, the modelling scheme has only been implemented for lacustrine fish habitat but a corresponding scheme for streams is under development. Concepts in the modelling approach are applicable to any taxon or grouping of biodiversity in any ecosystem type. The approach to modelling lacustrine fish habitat suitability index values has several steps that address the suitability of habitat to fish proceeding hierarchically from; various life stages of individual fish species; individual fish species; groups of fish and; fish assemblages.

Life stage suitability:

- Simple suitability ratings are assembled by habitat attribute (Depth, substrate, and cover) for each life stage of each species in the assemblage being considered. Ratings of nil, low, medium, or high for each category of each attribute are rendered on a numerical scale as 0.0, 0.33, 0.67, and 1.0. Sample ratings for yellow perch, *Perca flavescens,* are shown in Figure 4.1. Aggregate assessments by life stage of habitat preference across the whole fish assemblage present in the Great Lakes show the high importance of shallow waters with softer substrates like sand and silt and with vegetation present (Figure 4.2).
- The suitability index value, of combinations of one category per habitat attribute across the set of attributes, is computed as the product of the simple independent suitability values. This creates a matrix, or cube, of suitability values (Figure 4.3).

Species suitability:

- For each species, the suitability matrices for the three life stages are weight-summed using a set of weights that sum to one.
- A fixed set of weights is used for all species in each application of Defensible Methods. For the default approach, all weights are equal which assumes that there is no a priori way of knowing

the relative importance of different life stages without a detailed assessment of the habitat-limited bottlenecks in a population's dynamics and productivity.

- Each species matrix is then rescaled, such that the sum of suitability values across all combinations of categories, cells in the matrix, equals 1. This provision ensures that that each species can only contribute 1 to any group suitability matrix.

Group suitability:

- Groups of fish species are formed using criteria that reflect either ecological life style preferences, e.g. thermal (warm-, cool-, and cold-water) or trophic (piscivore, and non-piscivore), or human use preferences, e.g., commercial, sport and forage species, or other reasonable criteria. In site-specific applications of Defensible Methods, a combination of thermal and trophic groupings has been used which usually results in six groups of species.
- The matrices for species in a group are summed and then rescaled so the maximum cell value is 1. Thus the group suitability matrix expresses relative suitability among cells but ensures that pools of group matrices are not influenced by differences in the number of species making up a group.

Assemblage suitability:

- Matrices from the groups are sum-weighted using a set of group weights that sum to 1. The group weights depend on the priorities of fishery management agencies and users and fundamental properties of the target ecosystem (size, maximum depth, nutrient status, etc.).

The suitability value matrices obtained at any of the 4 levels in the hierarchy of calculations can be used to evaluate the suitability of habitats in one or many locations.

As might be expected, for a modelling scheme based on combining habitat preferences for many species, the suitability values obtained for group and assemblage are correlated with integrated fish community measures such as species richness, abundance and biomass. In Severn Sound, an analysis of combined fish community and habitat assessment data collected in the littoral zone showed that fish measures for warmwater and coolwater groups, for the assemblage, and for Index of Biotic Integrity were significantly correlated with corresponding Defensible Methods-based habitat suitability indices (Table 4.1, Figure 4.4)(Minns, *et al.* in preparation).

This approach, which takes into account depth, substrate and cover, can be extended to other habitat attributes. At present, modelling for thermal and light habitat is under way for some species. Suitability maps for temperature and light will be developed separately. Shifting from physical habitat which is treated using 2-dimensional models to dynamic habitat attributes with 3- and 4-dimensional features poses a significant analytical challenge.

4.2.2 Habitat Attribute-Spatial Unit Mapping

To apply the suitability models to ecosystems and to identify those areas and locations with higher or lower suitability for supporting fish biodiversity, the habitat attributes used in the development of the suitability values must be mapped across locations. The spatial extent of the required map coverage will depend on the objectives of the assessment exercise. For the ABIA project, the Great Lakes Basin is the target area but assembling map coverage of habitat attributes for that whole region is not possible at present. Instead, Lake Erie and its basin have been selected for the initial test of the predictive power of habitat suitability models (see Section 4.3 below).

Separate map layers are prepared for each habitat attribute in a geographical information system (GIS). The map layers are then intersected, or overlaid, to identify spatial polygons with unique combinations of habitat attributes. The overlay step brings the maps of all habitat attributes into a single map layer. Differences in polygon boundaries are incorporated to produce a map with many polygons. Each overlay polygon has one category from each habitat attribute identified. This combined map is known as a unique conditions map. For example, if depth, substrate and vegetation map layers are overlaid, there might be spatial polygons in sheltered nearshore locations with depth in the range 0 to 1 metres; substrate consisting of sand (60%), silt (30%), and clay (10%); and submerged vegetation cover of 60%.

4.2.3 Spatial Unit-Fish Species/Life stage Suitability Mapping

Linking the Fish Species/Life stage-Spatial Unit suitability index models to Habitat Attribute-Spatial Unit mapping requires three steps:

1) The overlay of separate habitat attribute maps to obtain a unique conditions map,
2) Development of a series of correspondence tables linking the categorical elements for each attribute in the suitability models and the habitat attribute-spatial unit maps, and
3) Attachment of suitability values to each unique polygon in the overlay map.

Completion of these steps results in the production of a series of location suitability maps.
The correspondence tables linking Fish Species/Life stage-Habitat Attribute suitability matrices to Spatial Unit-Habitat Attribute maps is necessary because it is difficult to obtain the same classification schemes for all sources of data. For instance, while substrate suitability values are specified for discrete categories of substrate (e.g. sand, boulder, clay), field mapping of substrate may identify either new categories representing mixtures of the discrete categories (e.g. sandy-gravel, silty-clay, etc.) or proportions of discrete substrates present (e.g. 30% gravel+60% sand+10% silt, etc.). If the field data consists of categories representing mixtures, the correspondence tables must indicate the expected proportional composition, based on expert opinion of by inference from available compositional data, e.g. sandy-gravel = 70% gravel+30% sand. Similar approaches are used for other habitat attributes. Once the proportions have been established in the correspondence tables, weighted suitability values can be computed for field-based map categories.

With the suitability models and correspondence tables in place, the assignment of suitability values to polygons in the overlay map is straightforward. Life stage, species, group and assemblage suitability values can be assigned to overlay map polygons and suitability maps generated. The suitability maps can be analyzed in several ways:

1) The maps can be classified by assigned non-overlapping ranges of suitability to categories, e.g. 0.0-0.3 low, 0.3-0.7 medium, 0.7-1.0 high,
2) Areas in particular suitability ranges can be determined,
3) Weighted-suitable areas, the sum of area multiplied by suitability across all polygons, can be computed as an area equivalent measure of habitat supply.

4.2.4 Comparison of Suitability Maps with the Distribution of ABIAs

The comparison of ABIA nominations with biodiversity maps will be a straightforward process. The candidate ABIAs can be classified into a series of classes depending on the criteria used to identify them. The suitability maps are developed with a continuous scale from 0 to 1 but can be reclassified into categorical maps with ranges of suitability from poor through to excellent. ABIA and Suitability class values can be cross-tabulated with the expectation that ABIAs will be more strongly associated with high suitability classes or values.

4.3 Outline of Approach for Lake Erie Basin

Work has begun on a habitat supply analysis for fish biodiversity in the Lake Erie Basin and results will be reported at SOLEC 2000. Lake Erie was selected because 1) Pilot-scale mapping activities have already been undertaken (Minns *et al.* 1997, 1998); 2) Much effort is going into the definition of fish habitat suitability models linked to population models for several key fish species in the lake; and 3) Significant changes are occurring in the ecosystem with major habitat impacts.

The habitat supply analysis for Lake Erie will cover all aquatic habitats in the lake, in the tributaries, and in the connecting channels. The many habitat feature maps will be compiled from existing sources rather than from new, expensive data collection programs. There are sufficient extant data, or where necessary the means to infer or extrapolate, to provide a substantive test of the predictive power of this approach to the identification of ABIAs in the Great Lakes Basin.

4.4 Sample of Expected Results

Several previous studies have provided preliminary evidence of the feasibility of the habitat supply analysis approach in Lake Erie, in Long Point Bay on Lake Erie, and in Severn Sound on Georgian Bay. These pilot projects illustrate the potential of this approach.

In a prototype for the Lake Erie HSA, Minns and Bakelaar (1998 in press) used available bathymetric and substrate data and an inferred map of submerged vegetation cover in conjunction with the Defensible Methods approach described in section 4.2 above to predict habitat suitability maps in the Canadian waters of Lake Erie. Suitability maps were developed for major groupings of fish based on thermal and trophic preferences and for selected species (Figure 4.6). These maps are based on physical habitat considerations alone and thermal habitat was not considered. The maps show limited areas of suitable habitat for coldwater non-piscivores in the central and eastern basins of the lake and extensive areas for walleye throughout the lake. The habitat supply analysis work currently under way in support of the SOLEC and other efforts is a direct outcome of that work.

More recently, Minns *et al.* (1998 in revision) undertook a more limited study of the Long Point Bay area in Lake Erie, taking advantage of a detailed aerial remote sensing study to map nearshore habitats in 1994. A suitability model was used to assessment habitat supply for three life stages in northern pike (*Esox lucius*, L.) and the supply estimates were used with Minns *et al.*'s (1996) population model for pike to predict potential biomass and production in the Bay area. There were also efforts in the Long Point study to assess thermal habitat in 4-dimensions, daily over the year by area grid and depth. The thermal and physical indices have yet to be combined. The suitability maps obtained for the Long Point area illustrate the potential for assessing the importance of contiguity (Figure 4.6). The dark areas represent fifty percent of the weighted suitable area, i.e., the product of area and suitability by unique habitat area, with the greatest suitability values. The higher quality habitats for each life stage do not overlap much but rather are intermingled thereby minimizing the distances as organisms pass from one life stage to the next.

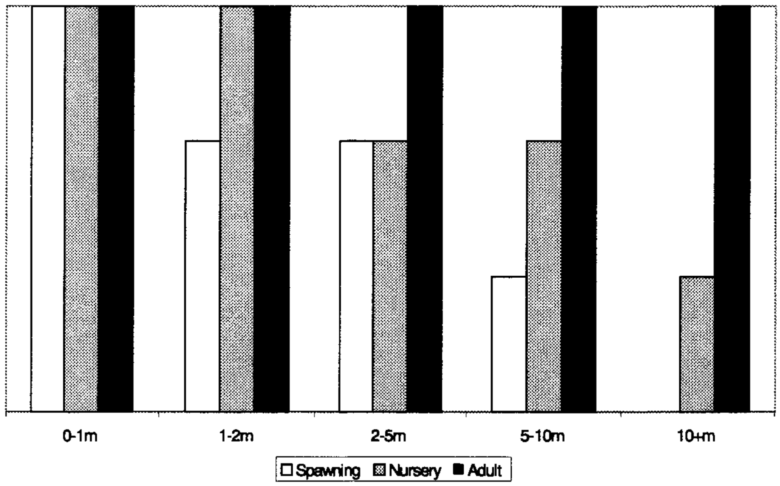
The third example from Severn Sound illustrates how the suitability maps that identify ABIAs might be used to guide local planning and development (Minns *et al.* in preparation). The nearshore habitat of the whole shoreline of Severn Sound on Georgian Bay was mapped over several years. The habitat data were assembled in a GIS and habitat suitability mapping performed (Figure 4.7). The figure shows a small portion at the mouth of Matchedash Bay. The suitability maps are being combined with wetland maps, maps identifying rare habitat features, and local knowledge of important fish habitats, to produce a colour-coded nearshore map. Areas are coded red, yellow, or green according to their importance as fish habitat. The colour scheme coordinates with a planning and development guidance document and the combined product will be used in local and regional planning offices to province first-cut guidance and direction for proposed development activities. Red areas have a higher fish biodiversity investment values and the types and scope of developed allowed will be more restricted than in green areas. Green areas are often sites where past neglect and ignorance led to a loss of habitat value and now represent important sites for habitat enhancement or creation.

Table 4.1. Pearson correlation coefficients between Defensible Methods suitability indices and fish community measure for standard survey transects in Severn Sound. [Values in bold-face are significant at P=0.05 after Bonferroni correction.]

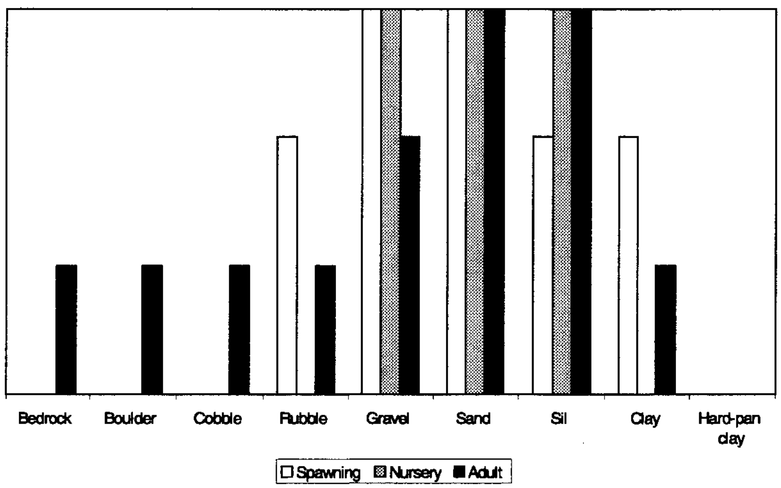
Defensible Methods Indices			Fish Capture Variables		
Thermal Category	Trophic Status	Life Stage	Species Richness	Density	Biomass
Warmwater	Non-piscivores	Adult	0.249	**0.383**	0.243
		YoY	**0.389**	**0.522**	**0.389**
		Spawning	0.171	0.265	0.180
	Piscivores	Adult	0.162	0.142	0.144
		YoY	0.208	0.198	0.182
		Spawning	0.172	0.139	0.157
Coolwater	Non-piscivores	Adult	**0.449**	**0.428**	**0.408**
		YoY	**0.456**	**0.460**	**0.374**
		Spawning	0.244	0.183	0.250
	Piscivores	Adult	0.120	0.133	0.100
		YoY	0.152	0.159	0.122
		Spawning	0.127	0.136	0.107
Coldwater	Non-piscivores	Adult	Insufficient Catch for Correlation		
		YoY	"		
		Spawning	"		
	Piscivores	Adult	None Caught		
		YoY	"		
		Spawning	"		
Composite Index Score vs Total Fish Variables			**0.396**	**0.442**	**0.319**

Figure 4.1. Habitat suitability ratings compiled for yellow perch, *Perca flavescens*, by habitat attribute: A) depth, B) substrate, and C) cover for each life stage. (Source: Lane *et al.* 1996 a,b,c).

A)



B)



C)

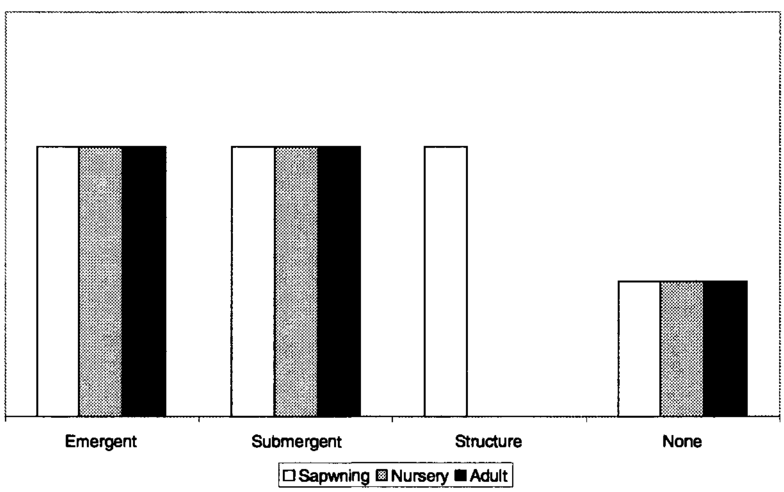
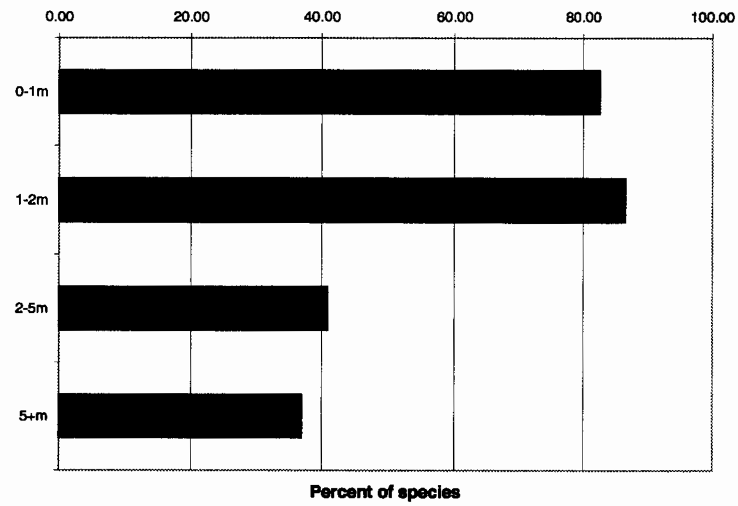
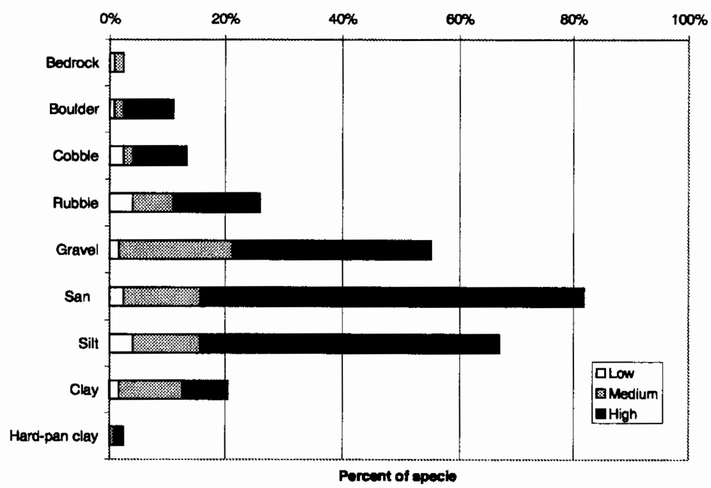


Figure 4.2. Aggregate use of habitat attributes A) depth, B) substrate, and C) cover by young-of-the-year of all fish species using lacustrine habitat in the Great Lakes. (Source: Lane *et al.* 1996 a,b,c).

A)



B)



C)

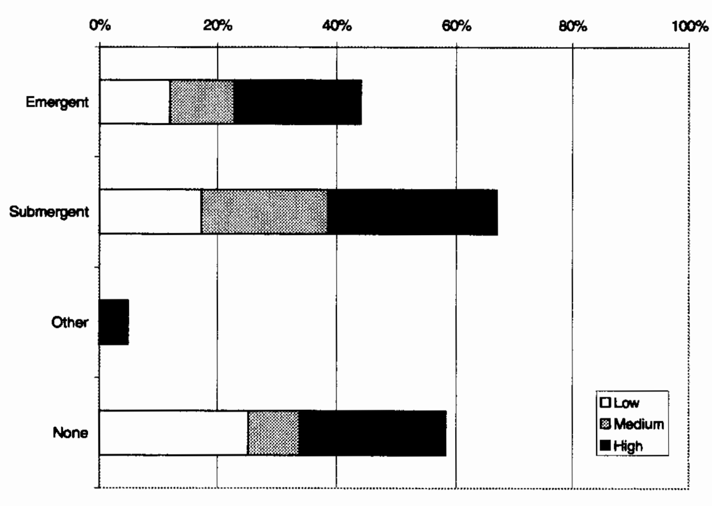


Figure 4.3. The matrix of combinations for the three habitat attributes, depth, substrate, and cover, used to estimate suitability values for the adult life stage of Great Lakes fish species.

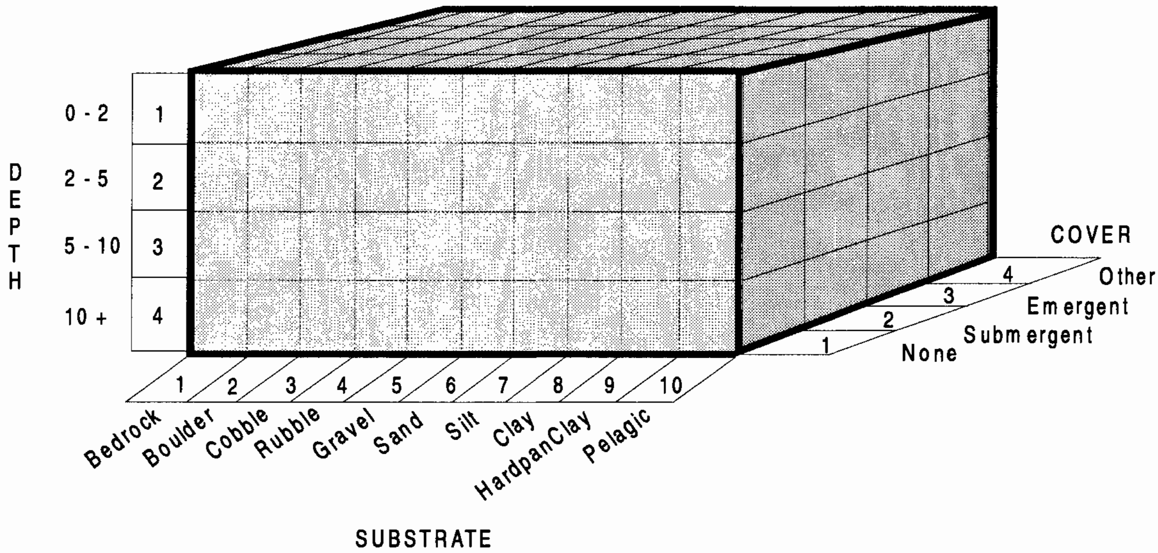


Figure 4.4. Graphs showing the relationships, and their statistical significance, between direct measures of the fish community (A - density, B - biomass, and C – species richness per standard electrofishing transect sample) composite habitat suitability index values obtained using the Defensible Methods approach of Minns *et al.* (1995) for littoral areas in Severn Sound, Georgian Bay.

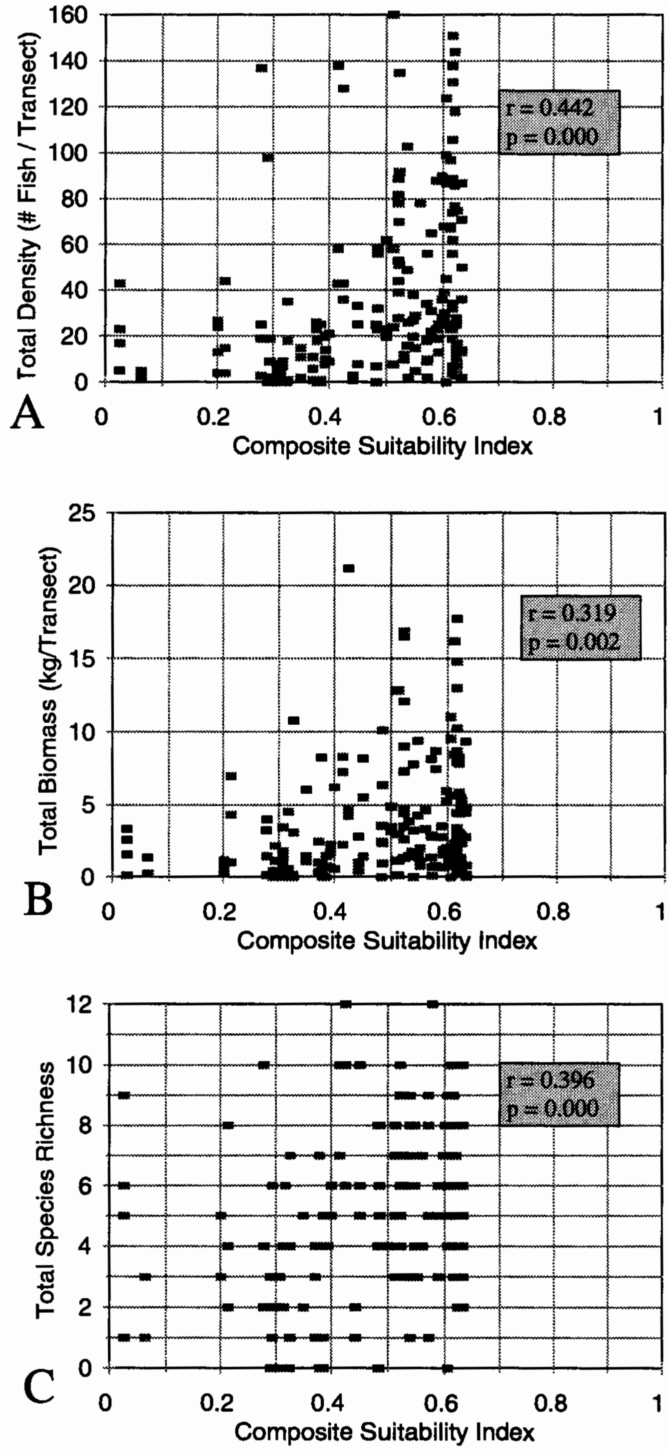


Figure 4.5. Habitat suitability index maps based on Defensible Methods ratings of physical habitat attributes without reference to thermal habitat for A) coldwater non-piscivorous fishes and B) walleye (*Stizostedion vitreum vitreum*) in the Canadian waters of Lake Erie.[Source: Minns and Bakelaar, 1998 in press].

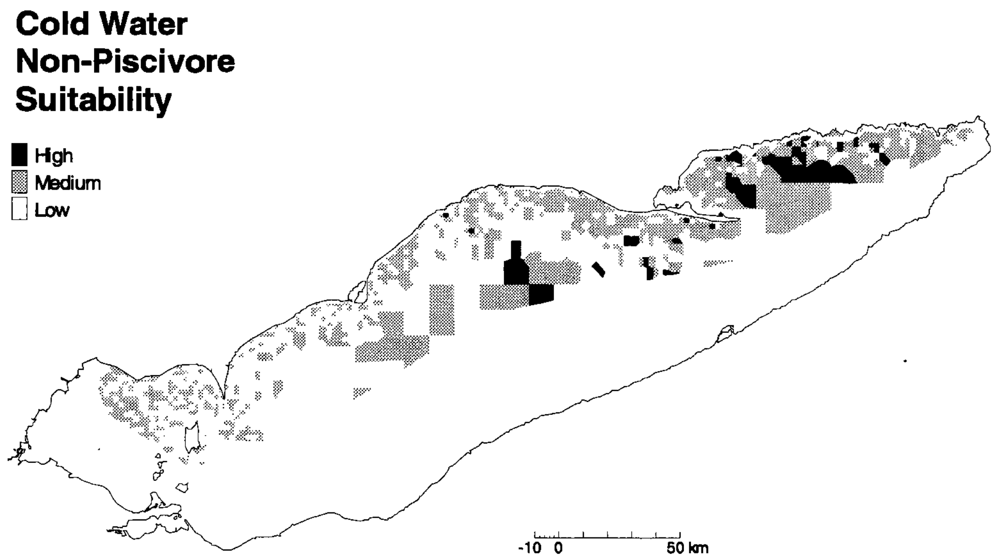


Figure 4.6. Habitat suitability maps based on Defensible Methods ratings of physical habitat attributes without reference to thermal habitat for three life stages of northern pike, *Esox lucius*: A) spawning, B) yoy or nursery, and C) adult in the Long Point region of Lake Erie.

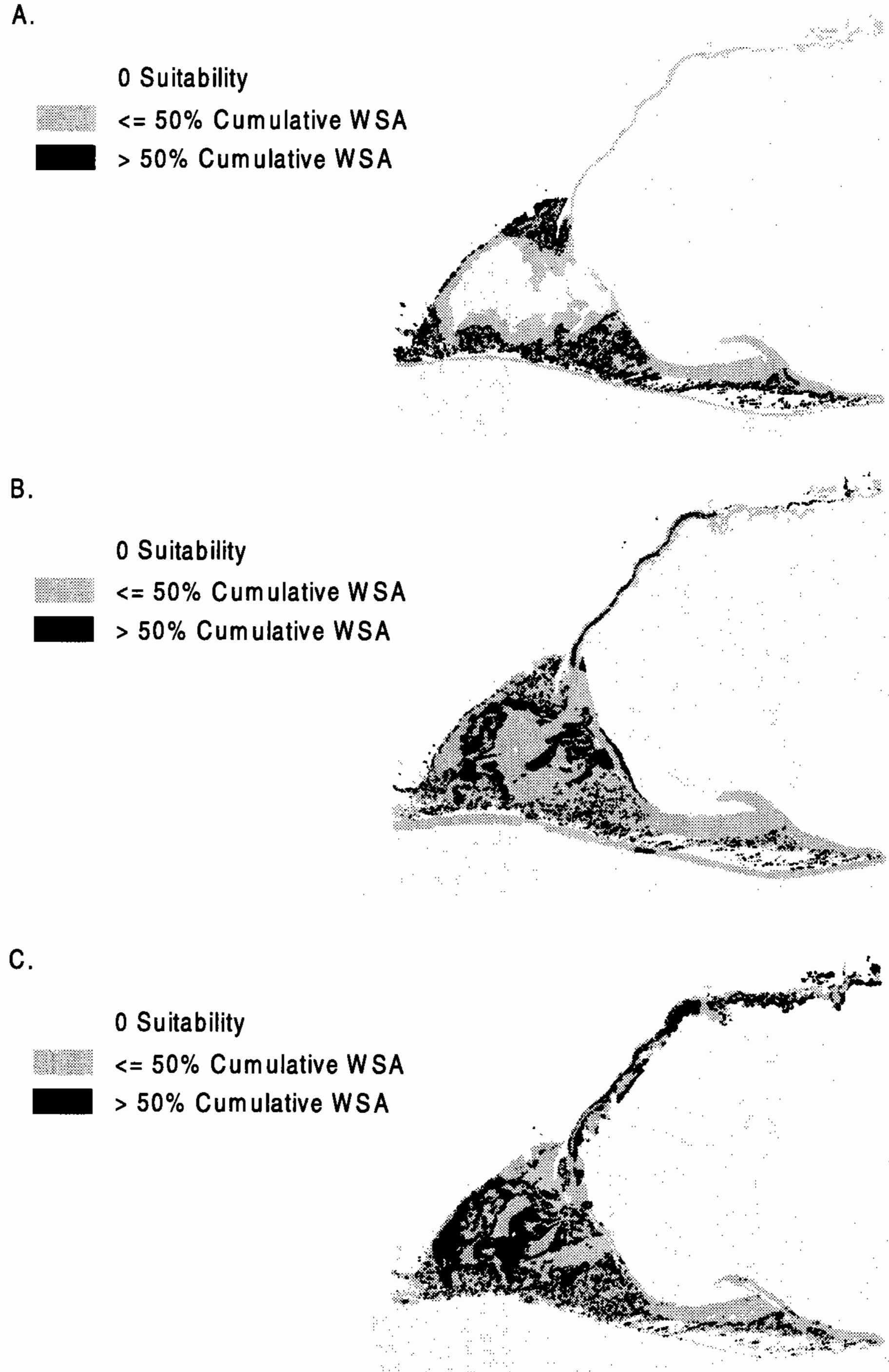
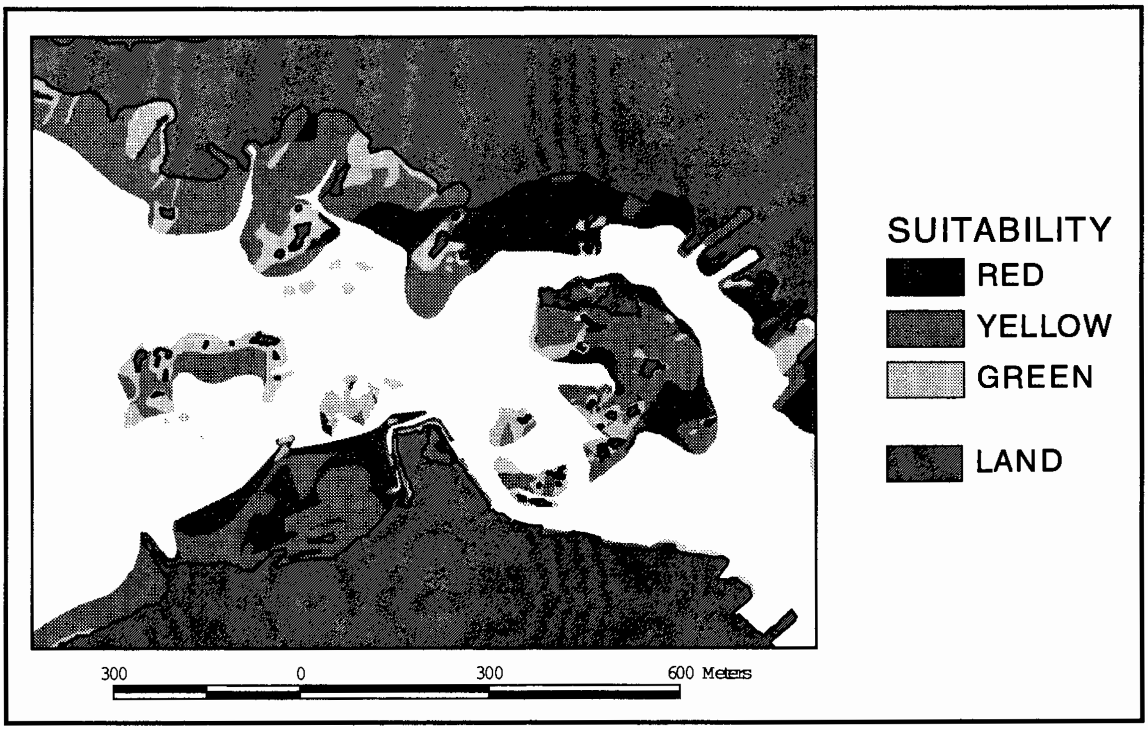


Figure 4.7. Habitat suitability maps based on Defensible Methods ratings of physical habitat attributes for part of Matchedash Bay, Severn Sound on Georgian Bay.



5. Status Indicators for ABIAs

Habitat Supply Analysis identifies areas within the Great Lakes that have the potential to support high biodiversity. In actuality, these areas may not be supporting levels of biodiversity that equal their potential. Consequently, the following schema has been proposed to classify ABIAs according to their current level of production and biodiversity. These classifications are:

- **Healthy** ABIAs – These are ecosystem locations that are relatively intact and functioning. **Conservation** efforts should be concentrated at these sites.
- **Damaged** ABIAs – These are locations that are damaged or degraded but that still retain the inherent capacity to support biodiversity and ecosystem functions if stressors are removed or ameliorated. **Restoration** efforts should be concentrated at these sites.
- **Lost** ABIAs – These are sites where past actions have led to their complete loss thereby, eliminating important contributors to biodiversity maintenance. **Creation** efforts should be directed to these sites where feasible.
- **Missing** ABIAs – These are sites where, because of their position in a sequence of locations or their contiguity to other locations, **enhancement** of habitat features would locally increase biodiversity and directly contribute to larger scale ABIA objectives.

Because of the high degree of connectivity among locations in aquatic ecosystems and the high level of mobility of many of the target biodiversity elements, it is unlikely that there are any areas that are not to some degree an ABIA. Thus within the four classes of ABIA, levels such as Low, Moderate, and High will be needed to distinguish the degree of actual or potential biodiversity investment contribution among locations (Table 5.1). Areas that are rated low may still be essential to the overall functioning of the ecosystem even if the relative contribution to maintenance of biodiversity and natural productivity appears to be low. For example, some locations may only be used on a transient basis as migration corridors between other locations supporting functions such as reproduction, rearing, or foraging. Such an ABIA classification scheme may have the most practical significance as a basis for priorizing conservation, restoration, creation, and enhancement activities. Furthermore, this scheme should ensure that no further loss or degradation of status in any ABIA occurs and, that necessary restoration, creation and enhancement activities will be used to achieve gains in status for some ABIAs.

Implementation of this classification scheme requires that all locations be assigned a class and a status or level. Various units can be used to quantify the coverage in each class by level combination. For example, lengths of streams and rivers, lengths of shoreline, areas of lake or wetland, etc., can be used as indicators. Change in class or level can be reported on a location specific basis or in aggregate for a region, a whole lake basin, or for the Great Lakes basin as a whole.

In this classification scheme, given that habitat impairment has been identified in nearly all AOCs, those candidate ABIAs identified in the survey would probably be classified as Damaged and then assigned status on their relative biodiversity contribution in a local and regional context. Many of the coastal wetlands, that have been lost to infilling, would be classified as Lost whereas other wetlands, that have been cut off from the lakes by dyking, would classified as Damaged. In AOCs and other areas where habitat creation has been undertaken, potential sites for islands and reefs might be classified as Missing once the opportunity has been noted. Such a location may be withdrawn from a Damaged-Low combination, banked as Missing-High while the means of effecting the changes are planned, and then re-entered as Healthy-High once the enhancement activity has successfully occurred.

Without a detailed analysis of habitat supply and effects on individual species, any assessment of status of the ABIAs in the Great Lakes with these criteria is premature. However, it is possible to illustrate the type of status assessment that will be possible by reviewing the contributions of the proposed framework to existing evaluations of habitat status. In a recently completed assessment of the state of Lake Erie, the Lake Erie Commission (1998) rated the aquatic habitat quality of Lake Erie shorelines and river mouths within Ohio. Using a Qualitative Habitat Evaluation Index (QHEI), they found that the overall shoreline rated only fair on a scale of poor, fair, good, and excellent and that the overall score for river mouth QHEI was poor (Tables 5.2 and 5.3).

Table 5.4 is a re-classification of the river mouth QHEI results using the proposed ABIA status classes. All of the tributaries in Ohio fall into a degraded class. With finer analysis of habitat structures within the tributaries, it becomes clear that there are some major losses of habitat (principally caused by dams or shoreline hardening). These losses in specific locations result in the following assessment by the Lake Erie Commission: "Currently, only three of nine lakeshore areas and two of the 11 river mouths possess habitat suitable to support healthy biological communities." The contrast between the only two river mouths that support healthy biological communities, namely the Grand River and Maumee River, is also instructive. Unlike the Grand River, the Maumee River outlet is continuous with an extensive coastal wetland complex that serves as a nursery area for river-run fish species such as walleye. While walleye are known to spawn in both the Maumee and Grand Rivers, the Grand River is not a major contributor to walleye recruitment in Lake Erie. The primary rivers are the Maumee and Sandusky. Despite its degraded status, the Sandusky River because of its proximity to nursery area would thus be a prime candidate for restoration efforts. The Grand River, in contrast, contributes less to lake-wide biodiversity and productivity because nursery habitat is limited or missing entirely. The Grand River in Ohio, therefore, would be a candidate for enhancement of missing habitat features.

Table 5.1. Hypothetical organization for the assessment of class, potential, and status based on evaluation of habitat features conditions across spatial units, or locations.

Spatial Units	Habitat features					Anaysis (HSA)	Class	Potential	Status
	1	2	3	4	...				
Wetland	H	M	M	H		➔	Damaged	High	60%
Reef	H	H	H	H	...	➔	Healthy	Medium	95%
Bay	H	L	M	H		➔	Lost	Medium	0%
Reef	M	L	M	L		➔	Damaged	Low	70%
Stream	L	L	L	H		➔	Missing	High	20%
Etc.	...					...	...		

Table 5.2. Average QHEI scores for Lake Erie shores with equivalent grade scores. Grades are A: excellent, B: good; C: fair, and D: poor. Data courtesy of R. Thoma, Ohio EPA.

Lake Erie shoreline regions

Area	QHEI	Grade
Lucus Co.	49.1	**D**
Ottawa Co.	49.0	**D**
Erie Co.	56.0	**B**
Lorain Co.	55.6	**B**
Cuyahoga Co.	51.0	**C**
Lake Co.	53.4	**C**
Ashtabula Co.	52.1	**C**
Sandusky Bay	48.5	**D**
Lake Erie Islands	63.2	**A**
Lake shore average	53.4	**C**

Table 5.3. Average QHEI scores for Lake Erie tributaries. Lacustuary scores with lacustuary habitat grades, dam locations and miles of free flowing stream below dams. The overall tributary habitat grade is also given. Tributary habitat grades are calculated using the lacustuary QHEI grade and the amount of free flowing stream (below dams) that is available to spawning fish from Lake Erie. Grades are A: excellent, B: good; C: fair, and D: poor. Data courtesy of R. Thoma, Ohio EPA.

River system	Lacustuary QHEI	Tributary grade	Lacustuary habitat grade	Dam location*	Miles of free flowing stream below dam
Maumme R.	50.9	C	**B**	32.2	17.4 mi.
Portage R.	54.2	C	**D**	20.8	5.8 mi.
Sandusky R.	43.6	D	**F**	18.0	2.3 mi.
Huron R.	52.1	C	**D**	14.6	4.3 mi.
Vermilion R.	48.0	D	**C**	23.7	21.8 mi.
Black R.	49.9	D	**C**	No dam	N/A
Cuyahoga R.	34.0	F	**D**	20.7	13.9 mi.
Chagrin R	53.7	C	**D**	4.8	3.4 mi.
Grand R.	52.4	C	**B**	30.9	26.7 mi.
Ashtabula R.	48.2	D	**C**	No dam	N/A
Conneaut Cr.	41.0	D	**C**	20.4	18.9 mi.
Average	47.2	D	**D**	N/A	N/A

* Dam location given as number of miles upstream of the confluence of the tributary with Lake Erie. This distance includes the portion of river affected by Lake Erie water levels.

Table 5.4. ABIA status of river mouth habitats on the Ohio shore of Lake Erie, based on the results of R. Thoma, Ohio EPA.

River system	Lacustuary habitat grade	Miles of free flowing stream below dam	ABIA Class
Maumme R.	**B**	17.4 mi.	Degraded
Portage R.	**D**	5.8 mi.	Degraded
Sandusky R.	**F**	2.3 mi.	Degraded
Huron R.	**D**	4.3 mi.	Degraded
Vermilion R.	**C**	21.8 mi.	Degraded
Black R.	**C**	N/A	Degraded
Cuyahoga R.	**D**	13.9 mi.	Degraded
Chagrin R	**D**	3.4 mi.	Degraded
Grand R.	**B**	26.7 mi.	Degraded
Ashtabula R.	**C**	N/A	Degraded
Conneaut Cr.	**C**	18.9 mi.	Degraded
Average	**D**	N/A	Degraded

6. Conclusions and Recommendations

While this report is an interim report of a work-in-progress, it is already possible to drawn several conclusions and make some recommendations that will affect how this work proceeds in preparation for SOLEC 2000.

- **Conceptual Framework:**
    - Accept that the terrestrial BIA scheme created for SOLEC 96 is not directly transferable into an ABIA scheme because of key structural and functional differences between terrestrial and aquatic ecosystems.
    - Recognize that the three axis model linking biodiversity, habitat attributes and spatial units provides a strong basis for integrating ecosystem assessments and has many potential applications when translated into an operational methodology.

- **Surveying for Candidate ABIAs:**
    - Recognize the subjective nature of candidate areas identified by experts in a non-quantitative context.
    - Continue to gather candidate ABIAs recommended by experts around the Great Lakes Basin as a means of clarifying the concept of ABIAs and as a test-bed for the quantitative approach (HSA).
    - Expand the scope of information gathered in the survey approach.
    - Implement method of gathering survey data using an Internet web-site.
    - Implement a semi-automated method for updating the candidate database and updating the web-site.

- **Habitat Supply Analysis:**
    - Complete the prototype application of the HSA approach for the Lake Erie Basin for fish species assemblages using the aggregate Defensible Methods approach to suitability modelling and compare the results with the survey-based candidate ABIAs.
    - Carry through the development of habitat supply data for individual species using more detailed suitability models and link the supply results via density dependent functions to population models.
    - Pursue analysis of contiguity issues arising for sequences of life stages within species and for interaction between species in assemblages and communities.

- **Status Indicators:**
    - Develop further the class, potential, status approach to indicators for ABIAs drawing on the Lake Erie HSA to derive quantitative results and to identify habitat management strategies.

7. Acknowledgements

This work was undertaken with the support and encouragement of the Habitat Advisory Board of the Great Lakes Fishery Commission. Financial contributions and equivalent support came from U.S. Environmental Protection Agency, Environment Canada, Great Lakes Fishery Commission, Fisheries and Oceans Canada. We especially want to note the continuing advice and encouragement given by Dr. Kent Fuller with U.S. E.P.A and Dr. Harvey Shear with Environment Canada. We want to note the assistance and support of members of the Lake Erie Committee and their Environmental Objectives task group. We thank Roger Thoma with Ohio Environment Protection Agency for his help with the data and advice. We want to recognize the contributions of Carolyn Bakelaar and Peter Brunette, GIS Consultants, in the map- and web-related aspects of the project activities. Many other individuals and agencies have assisted the project team with data and information acquisition. We thank all those in the Great Lakes community who have responded to the request for candidate ABIAs, including those not yet incorporated into the database and web-site.

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1.2 http://geonames.nrcan.gc.ca/
1.3 http://mapping.usgs.gov/www/gnis/gnisform.html

9. Appendices

Appendix 1. English and French versions of the mail-out questionnaire for ABIA nominations.

SOLEC '98 Questionnaire to Identif

Aquatic Biodiversity Investment Areas in the Great Lakes Basin

Who are you and who do you represent?		
Name:	Position:	Agency:
Address:		
Phone:	Fax:	Email:

Candidate Aquatic Biodiversity Investment Area (ABIA)			
What is the location? (Please be as specific as possible):			
Great Lakes Basin unit (✓ one):		Main feature (✓ up to 3):	Other location features:
Lakes: ❍ Superior ❍ Michigan ❍ Huron ❍ St. Clair ❍ Erie ❍ Ontario	River: ❍ St. Mary's ❍ St. Clair ❍ Detroit ❍ Niagara ❍ St.Lawrence	❍ Tributary ❍ Wetland ❍ Reef nearshore ❍ Embayment ❍ Reef offshore ❍ Pelagic ❍ Island(s) ❍ Profundal ❍ Tableland ❍ Shorelands ❍ Beach	Briefly describe... ____________________ ____________________ ____________________ ____________________ ____________________ ____________________

Why is this a candidate ABIA?		
Checklist (✓ up to three):	Biodiversity (name):	Other criteria:
❍ High biodiversity ❍ High productivity ❍ Critical for rare spp. ❍ Critical for economic spp. ❍ Critical for endangered spp. ❍ High habitat diversity ❍ Rare habitat features ❍ High connectivity value	Community (i.e. fish, bird, etc.):__________ Sub-community (i.e. cold water, warm water, etc.): ____________________ Species: ____________ ____________________ Life stage(s): __________ ____________________ ____________________	Briefly describe... ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________

Please **FAX** or **MAIL** your response(s) to: Attn: Dr. Heather A. Morrison
Great Lakes Laboratory for Fisheries and Aquatic Sciences, DFO
PO Box 5050, 867 Lakeshore Road, Burlington, Ontario L7R 4A6 CANADA
Phone: (905)-336-4497 **FAX (905)-336-6437** Email: morrisonh@dfo-mpo.gc.ca
N.B. One candidate per sheet. Submit multiple sheets, stapled together if needed.

SOLEC'98 Questionnaire d'identification des

Zones d'Investissement dans la Biodiversité Aquatique de la région des Grands Lacs

Qui êtes-vous et qui représentez-vous?

Nom:	Poste:	Agence:
Adresse:		
Téléphone:	Télécopieur:	Adresse électronique:

Candidat à la Zone d'Investissement dans la Biodiversité Aquatique (ZIBA)

Où est-elle située ? (Soyez aussi précis que possible):

Élément dans le bassin des Grands Lacs (Cochez-en une seule):		Caractéristique principale (Cochez-en 3 au maximum):	Autres caractéristiques de l'endroit:
Lacs: ❍ Supérieur ❍ Michigan ❍ Huron ❍ St. Clair ❍ Érié ❍ Ontario	Rivières: ❍ St. Mary's ❍ St. Clair ❍ Détroit ❍ Niagara ❍ Le Saint-Laurent	❍ Affluent ❍ Marécages ❍ Récif frangeant ❍ Baie ❍ Récif-barrière ❍ Pélagique ❍ Ile(s) ❍ Benthique ❍ Table de terre ❍ Littoral ❍ Plage	Décrivez brièvement...

Pourquoi est-ce un candidat ZIBA ?

Liste de contrôle (Cochez-en 3 au maximum):	Biodiversité (nom):	Autres critères:
❍ Biodiversité élevée ❍ Productivité élevée ❍ Essentielle pour les espèces rares ❍ Essentielle pour les espèces commerciales ❍ Essentielle pour les espèces menacées ❍ Diversité élevée de l'habitat ❍ Caractéristiques rares de l'habitat ❍ Importante valeur de rapports	Communauté: _____ Sous-communauté: _____ Espèces: _____ Stade(s) de développement: _____	Décrivez brièvement...

Veuille **TÉLÉCOPIER** ou **POSTER** votre/vos réponse(s)à l'attention de: Dr. Heather Morrison, Great Lakes Laboratory for Fisheries and Aquatic Sciences, DFO, Boîte Postale 5050, 867 Lakeshore Road, Burlington, Ontario L7R 4A6, CANADA.
Téléphone: (905) 336-4497 **Photocopieur: (905) 336-6437**
Adresse électronique: morrison@dfo-mpo.gc.ca
N.B. *Un candidat par page. Envoyez plusieurs feuilles, agrafez-les si nécessaire.*

Appendix 2. Descriptions of sites within the Great Lakes basin that have been nominated as Aquatic Biodiversity Investment Areas (ABIAs) as of August 31, 1998.

Site #	Site Name	Watershed	Location Features	Attributes	Comments about Site	Comments about Attributes of Site	Experts
68	Humbug Marsh	Detroit River	Tributary, Wetland	High Biodiversity, High Productivity, Critical for Rare Species, Critical for Economically Important Species, Critical for Endangered Species, Rare Habitat Features, High Connectivity	Last remnant Great Lakes coastal marsh on the 32-mile Michigan shoreline of the Detroit River.	Migration route for the 117 species of fish that inhabit the Great Lakes; for the 27 species of waterfowl that frequent Michigan's coastal wetlands; the more than 17 species of raptors, including eagles, hawks, and falcons; the more than 48 species of non-raptors, including loons, warblers, neotropical songbirds, cranes, and cattle egrets, and numerous species of butterflies that migrate annually from Canada to the southern United States and South America.	Dr. Bruce Manny (U.S. Geological Service)
7	Grand River in Ohio	Erie	Tributary	High Biodiversity, High Productivity, Critical for Rare Species	Wild and scenic river in Ohio. Many fish and freshwater mussel species.	The Grand River is under development pressure and appears to be vulnerable to degradation from urbanization.	Ms. Donna Myers (U.S. Geological Service)
1	Long Point	Erie	Wetlands, Nearshore Reef, Embayment	High Biodiversity, High Productivity, Critical for Rare Species, Rare Habitat Features		This site supports one of the largest and most diverse areas of aquatic vegetation in Lake Erie.	Dr. Jim Sherry (Environment Canada); Dr. Charles Minns (Fisheries and Oceans Canada)
54	Maumee River, Maumee Bay and coastal shorelands	Erie	Tributary, Embayment, Shorelands	Critical for Economically Important Species		Reproductive habitats for the various walleye life stages are linked by physical processes and function as a unit. These habitats are critical/essential for walleye reproduction and they exist no where else in space or time for this stock.	Mr. David Davies (Ohio Division of Wildlife)
10	Old Women Creek Estuary	Erie	Tributary, Wetlands, Shorelands	High Biodiversity, High Productivity, Rare Habitat Features		This site is a state nature preserve and national estuarine research reserve.	Dr. Rosanne Fortner (Ohio State Sea Grant)
13	Point Pelee National Park Wetlands	Erie	Wetlands, Shorelands, Beach	High Biodiversity, Critical for Rare Species, Critical for Endangered Species	The park is a RAMSAR International Wetland. Point on N. shore of Lake Erie - 1100 hectares of marsh plus barrier beaches and associated uplands.	There is much literature supporting the importance of this site to fish biodiversity.	Mr. Bill Stephenson (Parks Canada)
4	Presque Isle Bay and Associated Wetlands	Erie	Wetlands, Embayment, Beach	High Biodiversity, Critical for Rare Species, Critical for Endangered Species, High Habitat Diversity, Rare Habitat Features	Sandspit arcs towards mainland to form large, shallow embayment with aquatic plant beds, emergent marsh, shallows, beaches and mussel beds.	This site supports rare species including the bowfin, spotted gar, Iowa darter, lake sturgeon, eastern sand darter and Great Lakes muskellunge. Furthermore, this site supports approximately 20 species of freshwater mussels and several rare fish species; productivity and species diversity are high.	Mr. Roger Kenyon (Pennsylvania Fish and Boat Commission); Mr. Charles Bier (Western Pennsylvania Conservancy)

Site #	Site Name	Watershed	Location Features	Attributes	Comments about Site	Comments about Attributes of Site	Experts
58	Rondeau Bay	Erie	Embayment	High Productivity, High Habitat Diversity			Mr. Jack Robinson (Lower Thames Valley County Authority)
64	Sandusky Bay	Erie	Embayment, Pelagic	High Productivity, Critical for Economically Important Species	Rare habitat in the Great Lakes. Area supports high productivity of phytoplankton.		Dr. Robert Heath (Kent State University)
53	Sandusky River and Sandusky Bay	Erie	Tributary, Wetlands, Embayment	High Productivity, Critical for Economically Important Species, High Connectivity		Very important for sustaining walleye populations in Lake Erie.	Mr. David Davies (Ohio Division of Wildlife)
57	Spooner Creek	Erie	Tributary	High Productivity	This creek is the uppermost tributary to Cattaraugus Creek, New York's largest Lake Erie tributary, and is located just downstream of the Springville Dam, which forms an upstream barrier to anadromous fish movements in Cattaraugus Creek. A 12.8 square mile watershed; 1.5% gradient; 14C - 15C mean Sept. temp.; wild sthd. Population, approx 6000 YOY per ha.; deep cut forested channel; spring seeps	This land is privately owned and has limited public access. Creek supports steelhead, darter, Cyprinidae, sculpin.	Mr. Floyd Cornelius (New York State Department of the Environment)
63	St. Clair River Delta/Lake St Clair	Erie	Wetlands, Embayment, Shorelands, Islands	High Biodiversity, High Productivity, Rare Habitat Features, Critical for Rare Species, High Connectivity	Submergent and emergent macrophytes. Shallow, warm and productive waters. Migratory route for valuable fish populations from Lakes Erie and Huron.	One of the last remaining stretches of natural shoreline, spawning and nursery ground for numerous fish species. Most diverse native plant, vertebrate, and invertebrate communites in Great Lakes.	Dr. Tim Johnson (Ontario Ministry of Natural Resources); Dr. Heather Morrison (Aqualink); Mr. Robert Haas (Michigan Department of Natural Resources)
11	Sydenham River	Erie	Tributary	High Biodiversity, Critical for Rare Species, Critical for Endangered Species, Rare Habitat Features		The Sydenham River supports the richest fresh-water mussel community in Canada including many rare and endangered species of mussels. It also supports other threatened and endangered species including the spiny softshelled turtle, eastern sand darter. The river should be declared an ecological preserve to protect its rare Carolinian flora and fauna from intensifying agricultural practices.	Dr. Janice Smith (Environment Canada); Ms. Muriel Andreae (St. Clair Region Conservation Authority)
56	Tonawanda Creek Watershed	Erie	Tributary	High Biodiversity, Critical for Rare Species			Mrs. Kathryn Schneider (New York State Department of the Environment)

Site #	Site Name	Watershed	Location Features	Attributes	Comments about Site	Comments about Attributes of Site	Experts
55	Western Basin Reef Complex	Erie	Offshore Reef, Nearshore Reef, Shorelands, Islands	High Productivity, Critical for Economically Important Species, Rare Habitat Features	Physically complex structure; shallow, warm productive waters; macrophyte beds and diversity of substrate types. One of the few remaining areas of high quality nearshore habitat and biological communities along Ohio's shoreline.	This site provides spawning and nursery grounds for many fish species. Little undisturbed shoreline on mainland. Considerable habitat loss following colonization by zebra mussels. There is much literature supporting the importance of this site to fish biodiversity.	Mr. David Davies (Ohio Division of Wildlife); Dr. Tim Johnson (Ontario Ministry of Natural Resources; Dr. Jeffrey Busch (Ohio Lake Erie Office)
69	Baie du Dore	Huron	Wetlands, Embayment, Islands	High Biodiversity, High Habitat Diversity, High Connectivity	100 ha shallow coastal embayment and wetland opening northwest into Lake Huron. Underwood Creek Tributary is next to Douglas Point which is an Environmentally Sensitive Area and Scott Point ANSO. The mean depth is 2-3m and it contains an island and protective shoals.	Provincially significant class 2 wetland, 24 vegetation communities, 50% marsh, 46% fen, 4% swamp. Nursery, spawning, feeding migratory habitat for at least 50 species of fish. Breeding & feeding habitat for provincially significant waterfowl, birds, reptiles, and amphibians. More than 150 species of plants. Unique coastal habitat in eastern shore south to Sarnia.	Mr. Don Wismer (Ontario Hydro)
40	Big Sound Area - Parry Sound	Huron	Nearshore Reef, Embayment, Islands	Critical for Rare Species, High Habitat Diversity, High Connectivity		Only area outside of Lake Superior with significant natural reproduction of remnant lake trout.	Mr. John Fizsimons (Department of Fisheries and Oceans)
59	Bothwells' Creek	Huron	Tributary	High Biodiversity, Rare Habitat Features	This is the only fall/winter spawning ground of rainbow trout in Ontario. The gene pool of this population of rainbow trout is significantly different from the rest of the RT populations in the lake.	Unique temperature regime because water flows from underground springs and maintains a temperature of 4C-7C in the winter. The warm temperature induces native lake trout to spawn in Nov-Feb period, 2-3 months before spawning period.	Mr. Doug Dodge (Ontario Ministry of Natural Resources)
21	Dorans Bay	Huron	Embayment	Critical for Economically Important Species		This site provides whitefish habitat.	Ms. Ann Brindle (Grey Sauble Conservation Authority)
38	Fathom Five National Marine Park	Huron	Nearshore Reef, Pelagic, Islands	High Biodiversity, Rare Habitat Features	This area is characterized by embayments, wetlands, nearshore communities, bird colonies, open water.	Protected area. This area is 120 km2 national marine protected area. It is part of the Niagara Escarpment World Biosphere Reserve. Already the park has played an important role in focussing research and study in a relatively undisturbed area.	Mr. Scott Parker (Parks Canada)
19	Fishing Islands	Huron	Offshore Reef	Critical for Economically Important Species	This area is characterized by the abundance of sand shoals.	This site provides whitefish habitat.	Ms. Ann Brindle (Grey Sauble Conservation Authority)
49	North Shore of Lake Huron from Mackinac Straits to International line with Canada	Huron	Wetlands, Nearshore Reef, Embayment, Shorelands, Islands	High Biodiversity, Critical for Rare Species, Critical for Economically Important Species, High Habitat Diversity, Rare Habitat Features, High Connectivity	Composed of Niagara Escarpment, reef, island and sheltered waters. This escarpment is key to lake trout rehabilitation - historically 68% of spawning lake trout from MI waters were from here. Lake herring a state threatened species is also common here.	Nesting for shore birds in Les Cheneux Islands. Islands used by cormorants, terns, gulls, & variety of other birds.	Mr. James Johnson (Michigan Department of Natural Resources)

Site #	Site Name	Watershed	Location Features	Attributes	Comments about Site	Comments about Attributes of Site	Experts
39	Saginaw Bay	Huron	Tributary, Wetlands, Nearshore Reef, Embayment	High Biodiversity, High Productivity, High Habitat Diversity, Critical for Economically Important Species	Saginaw Bay offers a huge variety of habitat types such as very large stands of emergent grass wetlands and nearshore rocky bottom that are highly productive and which support a rich and diverse flora and fauna.	Saginaw Bay supports a rich flora and fauna through high rates of primary productivity and very protected shallow waters along with emergent grasses. Saginaw Bay and tributaries support extremely valuable sport fisheries for a variety of species, principally yellow perch and a recovering walleye population. The bay also supports a commercial fishery for whitefish, yellow perch and other species.	Dr. Dave Fielder (Michigan Department of Natural Resources); Dr. Russell Moll (Michigan Sea Grant); Mr. James Baker (Michigan Department of Natural Resources)
20	Sauble Beach	Huron	Beach	Critical for Economically Important Species	Provides whitefish habitat.	Ms. Ann Brindle (Grey Sauble Conservation Authority)	
22	Tank Range (near Meaford)	Huron	Shorelands	Critical for Economically Important Species		Provides whitefish habitat.	Ms. Ann Brindle (Grey Sauble Conservation Authority)
62	Clay valleys/ troughs off Black/ Kintzele Ditch	Michigan	Offshore Reef	Rare Habitat Features	Area offers extremely unique habitat of clay troughs ranging from 5-6 foot in height in water ranging from 15 to 30 ft. This differs from the typical sand-bottom of the lake.		Mr. Janel Palla (Indiana Department of Natural Resources)
18	Eight Inland lakes of northwestern lower Michigan	Michigan	Profundal	Critical for Rare Species, Rare Habitat Features	Deep coldwater lakes.	This site supports many coldwater stenotherms.	Dr. Daniel Mazur (U.S. Environmental Protection Agency)
9	Embayment South of Little Tail Point, located NW of Green Bay on Green Bay	Michigan	Embayment	High Productivity, Critical for Economically Important Species		The area south of Little Tail Point on Green Bay consistently has the highest abundance of YOY yellow perch in southern Green Bay.	Mr. Brian Belonger (Wisconsin Department of Natural Resources)
74	Fischer Creek	Michigan	Tributary, Wetlands, Shorelands	High Biodiversity, Critical for Economically Important Species	State Forest		Mr. Tom Herschelman
6	Grand River System	Michigan	Tributary, Wetlands, Islands	High Biodiversity, High Productivity, High Connectivity	Relatively undeveloped shoreline. At least twenty miles of the upstream watershed are protected.	Provides habitat for warm and cold water species. Provides drinking water for communities.	58
26	Grand Traverse Bay	Michigan	Nearshore Reef, Offshore Reef, Shorelands	Critical for Economically Important Species, High Connectivity		This site provides critical linkage to Grand Traverse Bay watershed.	Dr. Richard Schorfhaar (Michigan Department of Natural Resources); Mr. John McKinney (Michigan Sea Grant Program)

Site #	Site Name	Watershed	Location Features	Attributes	Comments about Site	Comments about Attributes of Site	Experts
60	Hammond Marina	Michigan	Embayment	High Biodiversity, High Productivity	Marina protected by rip-rap shoreline.	Inside/outside (around marina) possess diverse/ productive fish populations such as smallmouth bass; largemouth bass; various sunfish species; rock bass; carp; freshwater drum; johnny darters; shiners; alewife (etc.) in addition to the trout, salmon and yellow perch.	Mr. Janel Palla (Indiana Department of Natural Resources)
35	Little Bay de Noc from the mouth of the Whitefish River to the mouth of the Ford River	Michigan	Embayment	High Biodiversity, High Productivity, Critical for Economically Important Species	L.B. de Noc is approx. 34000 acres. It has 3 large tributary rivers and 4 smaller streams. It supports an important walleye sport fishery and a commercial fishery for whitefish. It is also an area of high biodiversity.		Mr. Dell Siles (Michigan DNR)
61	NIPSCO Dean Mitchell Generating Station	Michigan	Nearshore Reef	High Biodiversity, High Productivity	Heated discharge outlet of Generating station.	Concentrate trout and salmon species during winter/early spring months. Supports a great number of other species throughout the year.	Mr. Janel Palla (Indiana Department of Natural Resources)
27	St. Joseph River	Michigan	Tributary			An extremely degraded but previously valuable tributary.	Mr. Al Smith (Friends of the St. Joe River Association Inc.)
42	Thornberry, or Crooked Creek	Michigan	Tributary	High Biodiversity, Rare Habitat Features	Site is a gravel-sand bottomed cool water stream flowing into Green Bay. This unique habitat supports one of the only inland brook trout population in Brown County, WI.	Nursery area for self sustaining inland brook trout population. Cooperative investigations between Oneida nation and USFWS and USGS.	Mr. John Koss (Oneida Nation)
12	Wetland and tributary stream complex on the western shore of Green Bay in Marinette, Oconto, Brown and Shawano counties (Western Shore Coastal Zone)	Michigan	Wetlands, Tributaries	High Productivity, Critical for Economically Important Species, Rare Habitat Features	This area is a complex of interconnected tributary streams and pooled wetlands. They account for most of the wetlands associated with the Green Bay aquatic ecosystem. Range from inter-seichal to inland pooled wetlands	The entire western shore consists of wetland complexes associated with uplands in some areas. Some specific wetland systems produce in excess of 20,000 northern pike/per acre.	Mr. Richard Rost (Wisconsin Departmetn of Natural Resources)
24	Wetland located within the Illinois Beach State Park.	Michigan	Wetlands, Shorelands, Beach	High Biodiversity, Critical for Rare Species, Critical for Endangered Species, High Habitat Diversity, Rare Habitat Features	This site is characterized by young dune swale topography of the sandy bed of ancient glacial Lake Chicago along the present shore of Lake Michigan.	Communities on the parallel ridges and swales illustrate primary dune succession on progressively older, ancient lakeshore line inward from Lake Michigan.	Mr. Kirby Cottrell (Illinois Department of Natural Resources)
14	Wolf River system within the Menominee Indian Reserve	Michigan	Tributary, Shorelands	High Biodiversity, High Productivity, Critical for Rare Species, Critical for Economically Important Species, Critical for Endangered Species, High Habitat Diversity	The Wolf River is located within the Menominee Reservation. Internationally known for the productive sustained yeild forest.	The Wolf River is listed as a wild and scenic river within the Menominee Reservation.	Mr. Douglas Cox (Menominee Indian Tribe)

Site #	Site Name	Watershed	Location Features	Attributes	Comments about Site	Comments about Attributes of Site	Experts
43	Klydel Wetland	Niagara River	Wetlands	High Biodiversity, High Productivity, Rare Habitat Features	This wetland was originally 102 acres but only 60-70 acres remain. Desperately needs protection from illegal development and threatened development.	Endangered wetland in urban setting. Wetland is being used as a nature area for environmental education on the 9.3 acres that is owned by North Tonawanda School District. We're trying to save the rest.	Mrs. Elizabeth Kaszubski (Citizens for a Green North Tonawanda)
32	Black River draining into Prince Edward Bay	Ontario	Tributary, Wetlands	High Biodiversity, High Productivity, Rare Habitat Features, High Connectivity	Lengthy low relief tributary with extensive emergent/submergent vegetation. Somewhat degraded due to agricultural land use.		Dr. Charles Minns (Fisheries and Oceans Canada)
33	Cootes Paradise and Hamilton Harbor	Ontario	Wetlands, Embayment	High Biodiversity, High Productivity, High Connectivity	Undergoing restoration. Surrounded by urbanization and upstream agricultural stresses.	Critical part of a sequence of connected streams, wetland, bay, open lake, shore areas and open lake pelagic.	Dr. Charles Minns (Fisheries and Oceans Canada)
5	Credit River and adjacent waters of Lake Ontario	Ontario	Tributary	Critical for Rare Species, Critical for Endangered Species		OMNR project to restore the watershed, Atlantic salmon are native to the stream.	Dr. David Noakes (University of Guelph)
51	Ganaraska River	Ontario	Tributary, Wetlands, Shorelands	High Productivity, Critical for Rare Species, High Habitat Diversity	Headwaters in Oak Ridges moraine.Provides a diversity of habitat to support productive fish populations	Mrs. Heather Conroy (Ganaraska Region Conservation Authority)	
52	Greater Cataraqui Marsh	Ontario	Wetlands	High Biodiversity, Critical for Rare Species	Large cattail marsh.		Mr. Chip Weseloh (Canadian Wildlife Service)
2	Humber Bay Marshes	Ontario	Wetlands	High Productivity, High Habitat Diversity, High Connectivity	Well developed wetland in an urban setting.	Important recreational and educational value. Active feeding site for colonial waterbirds and wading birds. There is a presence of fur bearing mammals and seasonal fish spawning. Fish found in the area include rainbow trout, rainbow smelt, white sucker, lake trout and shad.	Mr. C. Gonsalves (Emery Creek Environmental Association)
15	Sandy Creek Estuary	Ontario	Tributary, Wetlands, Shorelands	High Biodiversity, High Productivity, High Habitat Diversity	Eastern Lake Ontario estuary complex.	Justaposition of stream, marsh, dune, shoreland, forest and agricultural crops.	Mr. R. Smardor (Great Lakes Research Consortium)
50	Wilmot Creek	Ontario	Tributary, Wetlands, Shorelands	High Productivity, Critical for Rare Species, High Habitat Diversity		Provides a diversity of fish habitat suitable for many species, including atlantic salmon, supports large rainbow trout population	Mrs. Heather Conroy (Ganaraska Region Conservation Authority)
25	Dickerson Island	St. Lawrence	Islands	High Biodiversity, Rare Habitat Features			Mr. Henry Lickers (Mohawk Council of Akwesashe)
8	St. Lawrence River	St. Lawrence	Wetlands, Embayment, Shorelands	High Productivity, Critical for Economically Important Species, Rare Habitat Features	Migratory route for economic important species such as the american eel. It is also growth habitat for eel.	Main nursery and migratory habitat for eels that are the basis of a commercial fishery - also member of the predatory fish community.	Dr. Peter Hodson (Queen's University)

Site #	Site Name	Watershed	Location Features	Attributes	Comments about Site	Comments about Attributes of Site	Experts
73	St. Marys River	St. Marys	Wetlands, Nearshore Reef, Islands	High Biodiversity, High Habitat Diversity, High Connectivity	The St. Marys offers not only a variety of habitat but also some unique environmental conditions.	The river offers a blend of many habitat types.	Dr. Dave Fielder (Michigan Department Natural Resources)
36	Allouez Bay Wetland and Kakagon/Bad River Slough Complex	Superior	Wetlands, Embayment, Shorelands	High Biodiversity, Critical for Economically Important Species, Rare Habitat Features			Mr. John Brazner (U.S. Environmental Protection Agency)
30	Batchawana Bay	Superior	Tributary, Wetlands, Embayment	High Biodiversity, High Productivity, Critical for Rare Species		Extensive fringing wetlands, much lost to shore-line development, diverse aquatic community and diverse shoreline habitat.	Mr. Ed Iwachewski (Ontario Ministry of Natural Resources)
44	Big Bay Reef	Superior	Nearshore Reef, Offshore Reef	High Productivity, Critical for Economically Important Species, Critical for Endangered Species			Mr. Mike Donofrio (Keweenaw Bay Indian Community)
29	Black Bay	Superior	Tributary, Wetlands, Embayment	High Biodiversity, High Productivity, Critical for Economically Important Species	North shore of Lake Superior between Thunder Bay and Nipigon Bay.	Most productive bay on Lake Superior, wide range of species, extensive fringe wetlands.	Mr. Ed Iwachewski (Ontario Ministry of Natural Resources)
72	Caribou Island Reef Complex	SuperiorOffshore Reef	High Biodiversity, High Productivity, High Habitat Diversity	The most variation in depth of any area of Lake Superior	Community is pelagic and benthic with the most abundant populations of humper and siscowet lake trout in Lake Superior. Associated species include sculpins, burbot, and coregonines.	Mr. James Peck (Michigan Department Natural Resources)	
17	Chequamegon Bay South End	Superior	Tributary, Wetlands, Beach	High Productivity, Critical for Economically Important Species, High Connectivity	Groundwater upwelling.	Wetlands important for migratory birds and cool water fishes. Ground water fed tributaries important for lake trout and salmon.	Mr. Thomas Busjahn (U.S. Fish and Wildlife Service)
47	Eagle River Shoals	Superior	Offshore Reef	High Productivity, Critical for Economically Important Species, Rare Habitat Features	4 mile long reef.	This site contains critical whitefish and herring habitat within management unit M1-3.	Mr. Mike Donofrio (Keweenaw Bay Indian Community)
46	Huron Islands	Superior	Offshore Reef, Islands	High Productivity, Critical for Economically Important Species, High Habitat Diversity	Small island complex surrounded by flats.	One of only a few lake trout spawning reefs in management unit M1-4	Mr. Mike Donofrio (Keweenaw Bay Indian Community)
45	Huron River Reef	Superior	Nearshore Reef, Shorelands	High Productivity, Critically for Economically Important Species, Rare Habitat Features	Most productive spawning reef inside Keweenaw Bay.		Mr. Mike Donofrio (Keweenaw Bay Indian Community)

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71	Isle Royale, Nearshore Waters	Superior	Nearshore Reef, Embayment, Islands	High Biodiversity, Critical for Rare Species, High Habitat Diversity	Location corresponds to boundaries of Isle Royale National Park.	This ABIA contains the only self-sustaining population of coaster brook trout in Michigan waters. Nearshore waters contain populations of humper, sisconet, and lean lake trout unique to the Great Lakes.	Mr. James Peck (Michigan Department Natural Resources)
28	Kaministiquia River	Superior	Tributary	High Biodiversity, High Productivity, Critical for Rare Species	Flows through the city of Thunder Bay into Lake Superior.	47 km from lake up to first barrier, most diverse fish community on Canadian side of Lake Superior, self sustaining population of Lake Sturgeon.	Mr. Ed Iwachewski (Ontario Ministry of Natural Resources); Mr. Bob Thomson (Ontario Ministry of Natural Resources)
48	Manitou Island	Superior	Nearshore Reef, Islands	Critical for Rare Species, Critical for Economically Important Species, Rare Habitat Features	A large island surrounded by a shallow reef.	This site contains spawning and nursery habitat critical to lake trout, whitefish, and herring.	Mr. Mike Donofrio (Keweenaw Bay Indian Community)
3	Nipigon River/ Nipigon Bay	Superior	Tributary, Embayment	High Biodiversity, Critical for Rare Species, Critical for Economically Important Species		River has a high biodiversity of fish species and a remnant population of brook trout. This is the last refuge for coaster brook trout. It also supports a recovering lake sturgeon and walleye population. It is the largest tributary to Lake Superior.	Mr. Bob Thomson (Ontario Ministry of Natural Resources); Mr. Ed Iwachewski (Ontario Ministry of Natural Resources)
66	Otter Cove, Pukaskwa National Park	Superior	Tributary, Wetlands, Embayment	High Biodiversity, High Productivity, Rare Habitat Features	Cove of Lake Superior; rare feature on North shore of Superior; wetland present which is rare in this area.	These wetlands are a very rare feature on north shore of Superior.	Mr. Frank Burrows (Canadian Heritage Parks Canada)
67	St. Louis River	Superior	Tributary, Wetlands, Embayment	High Productivity, Critical for Rare Species, Critical for Endangered Species	Large commercial harbor; area of concern; high value habitat; largest US tributary to Lake Superior.	Common tern nesting site; walleye spawning area for western Lake Superior; sturgeon restoration; significant remaining wetlands.	Ms. Karen Plass (St. Louis River Citizens Action Community)
31	Thunder Bay	Superior	Tributary, Wetlands, Nearshore Reef, Embayment, Shorelands, Pelagic	Rare Habitat Features, High Biodiversity, Rare Habitat Features	Some of the last remaining Great Lakes shoreline wetland habitat. Area has many shipwrecks that provide habitat for fish.	This site should be considered a marine sanctuary.	Dr. Dave Fielder (Michigan Department of Natural Resources); Mr. Alfred Beeton (Great Lakes Research Laboratory)
34	Traverse Island Reef	Superior	Offshore Reef	High Productivity, Critical for Economically Important Species, High Habitat Diversity	1/2 mile long natural spawning reef for lake trout.	This site has a variety of clean boulder and rock habitat in a pollution free zone, with little human activity.	Mr. Mike Jonofrio (Keweenaw Bay Indian Community)

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65	White River, Pukaskwa National Park	Superior	Tributary	High Biodiversity, High Productivity, Rare Habitat Features	Very productive river for Lake Superior region.	Rare river habitat for area.	Mr. Frank Burrows (Canadian Heritage Parks Canada)
70	Whittlesey Creek Watershed - Bad River Watershed	Superior	Tributary, Wetlands	High Biodiversity, Critical for Rare Species, Critical for Economically Important Species, Critical for Endangered Species, High Habitat Diversity, Rare Habitat Features, High Connectivity			Mrs. Laura Day (National Wildlife Federation)