THE SWEETWATER SEA

AN INTERNATIONAL BIODIVERSITY CONSERVATION STRATEGY FOR LAKE HURON

TECHNICAL REPORT

The Nature Conservancy
Environment Canada
Ontario Ministry of Natural Resources
Michigan Department of Natural Resources and Environment
Michigan Natural Features Inventory
Michigan Sea Grant
The Nature Conservancy of Canada

Prepared by the Lake Huron Biodiversity Conservation Strategy Core Team
in cooperation with the Lake Huron Binational Partnership

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The conservation strategy presented in this report reflects the input of over 200 experts representing over 100 agencies, conservation authorities, universities, and non-governmental organizations (see Appendix B). The project's Core Team coordinated and documented the strategy's development, including preparation of this report. Core Team members include: Rachael Franks Taylor, Patrick Doran, Doug Pearsall, Rebecca Hagerman, Matt Herbert, and Mary Khoury (The Nature Conservancy in Michigan); Amy Derosier (Department of Nature Resources); Barb Barton and John Paskus (Michigan Natural Features Inventory); Laura Kucey and Audrey Lapenna (Ontario Ministry of Natural Resources); Jen Read, Keely Dinse, Mary Bohling, and Brandon Schroeder (Michigan Sea Grant); Dan Kraus (Nature Conservancy of Canada); and Greg Mayne (Environment Canada).

The project also benefited from the ongoing guidance and support of the project Steering Committee members: Janette Anderson and Greg Mayne (Environment Canada); Jim Bredin and Michelle Selzer (Michigan Department of Environmental Quality); Ted Briggs (Ontario Ministry of the Environment); Pat Carr (Michigan Conservation Districts); Patrick Doran and Rachael Franks Taylor (The Nature Conservancy in Michigan); Bonnie Fox (Conservation Ontario); James Johnson and Abigail Eaton (Michigan Department of Agriculture); Dan Kraus (Nature Conservancy of Canada); Jason Laronde and Rhonda Gagnon (Anishinabek Nation); Mike McMurtry and Dave Reid (Ontario Ministry of Natural Resources); Tammy Newcomb and Amy Derosier (Michigan Department of Natural Resources); Scott Parker (Parks Canada); Jennifer Read (Michigan Sea Grant); Mike Ripley (Chippewa/Ottawa Resource Authority); Peter Roberts (Ontario Ministry of Agriculture); Jamie Schardt (U.S. Environmental Protection Agency); and Brian Tucker (Métis Nation).

NOTE: *Two Michigan agencies, the Department of Natural Resources and the Department of Environmental Quality, have now merged to form the Department of Natural Resources and Environment; the Steering Committee members' affiliation at the time of recruitment is included above.*

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EXECUTIVE SUMMARY

Lake Huron is an ecologically rich and globally significant ecosystem, but its biodiversity is at risk. Invasive species, climate change, water pollution, rapid and poorly planned residential and industrial growth, altered hydrology, and incompatible agricultural, fishery, and forestry practices are all having negative effects. Degradation and loss of historical habitat have been identified as major stressors to Lake Huron and its watershed.

The Lake Huron Biodiversity Conservation Strategy (LHBCS) is an international initiative designed to identify what actions are needed to protect and conserve the native biodiversity of Lake Huron. The most critical biodiversity threats and needs of the lake were determined through a collaborative, science-based process. The recommended strategies are meant to restore and conserve a functioning ecosystem. By applying a biodiversity focus to synthesize and prioritize existing related efforts, the LHBCS reaffirms and advances many existing complementary plans and initiatives. This project will increase awareness and collaboration among organizations and communities active in biodiversity conservation with the Lake Huron watershed, and provide a lakewide context to local conservation actions. The project was led by The Nature Conservancy, Environment Canada, Ontario Ministry of Natural Resources, Michigan Sea Grant, Nature Conservancy of Canada, Michigan Natural Features Inventory, and Michigan Department of Natural Resources and Environment.

Project Goals

- Assemble available biodiversity information
- Define an international vision of biodiversity conservation for Lake Huron
- Develop shared strategies for protecting important areas and abating threats
- Promote international coordination of biodiversity conservation
- Provide a framework for measuring, managing and reporting biodiversity conservation efforts
- Support, connect, and advance the efforts of previous and ongoing conservation planning efforts across the basin

The Lake Huron Biodiversity Conservation Strategy is the product of a two-year planning process involving nearly 400 individuals from more than 100 agencies and organizations from around the Lake Huron basin. The Nature Conservancy's Conservation Action Planning process – a proven adaptive management approach for planning, implementing and measuring success for conservation projects - guided the development of the Strategy. This approach helps project teams develop the most effective conservation strategies based on the best available scientific information. The Strategy incorporated scientific information through the scientific literature and consultation with experts. Workshops, conference calls, on-line surveys, and meetings provided many opportunities for organizations and individuals to contribute to and review the content of the Strategy.

This process produced the following, each of which comprises a chapter of this technical report:

- Selection of biodiversity features that represent the full suite of Lake Huron biodiversity and a health assessment for each feature – Chapters 3 and 4
- Identification and ranking of threats to Lake Huron biodiversity including in-depth analysis of the five most critical threats and how they affect biodiversity features – Chapter 5

- Recommended strategies at multiple scales to abate the most critical threats and enhance the health of the biodiversity features – Chapter 6
- Identification of priority biodiversity conservation areas for implementation of strategies based on spatial data analysis – Chapter 7
- Suggested next steps to implement recommendations – Chapter 8

Project Scope

The Lake Huron Biodiversity Conservation Strategy focuses on the conservation of the native biodiversity of Lake Huron. However, threats to biodiversity and the conservation actions needed to abate them may originate from the lake, inland areas in the basin, and some may even occur outside of the basin. Therefore, scope is dually defined as:

Biodiversity features scope: Lake Huron and associated nearshore and aquatic habitats. This scope focuses on what biological diversity we are trying to conserve.

Planning region scope: Lake Huron basin. This scope focuses on the geographic area that may impact the biological diversity of interest.

Selecting Biodiversity Features and Assessing Health

Biodiversity features were selected for their ability to represent the full suite of biodiversity within the project area, including its species, natural communities and ecological systems, which are referred to as nested features in Conservation Action Planning terminology. Each biodiversity feature's current "health" status, or viability, was evaluated by defining a set of science-based indicators representing the feature's landscape context, condition and size in the project area. Each indicator is assigned thresholds defining acceptable ranges of variation. These indicators and thresholds provide the basis for rating the status of each feature based on the best available information. Through literature review and expert consultation, work groups evaluated the indicators and developed suggestions for desired condition. The overall state of Lake Huron biodiversity was determined by aggregating the assessments of all the biodiversity features. All indicators are detailed in the technical report.

The following biodiversity features were selected:

Open Water Benthic and Pelagic Ecosystem: Open water ecosystem beyond the 30-meter bathymetric contour from the mainland or islands, including reefs and shoals
Nested feature examples: *Diporeia*, lake trout, whitefish.
Condition: FAIR – 20 indicators; 4 are at target, 6 are close to target, 10 are well below target

Nearshore Zone: Submerged lands and water column of Lake Huron starting at 0 meters (shoreline) and extending to 30 meters in depth, not including areas upstream from river mouths and riverine coastal wetlands.
Nested feature examples: walleye, yellow perch, lake herring, turtles.
Condition: FAIR – 23 indicators; 7 are at target, 9 are close to target, 7 are well below target

Native Migratory Fish: Native fish that migrate to and depend on tributaries, nearshore areas, or wetlands as part of their natural life cycles.
Nested feature examples: lake sturgeon, suckers, redhorse, walleye.
Condition: FAIR – 20 indicators; 6 are at target, 8 are close to target, 6 are well below target

Islands: Land masses within Lake Huron that are surrounded by water, including both naturally formed and artificial islands that are 'naturalized' or support nested targets.
Nested feature examples: colonial nesting waterbirds.

Condition: GOOD – 5 indicators; 4 are at target, 1 is close to target

Aerial Migrants: Migrants that have high fidelity to Lake Huron, and for which migratory corridors associated with the lake are crucial to their survival.
Nested feature examples: migratory birds, bats, butterflies, dragonflies.
Condition: FAIR – 18 indicators; 9 are at target, 9 are close to target

Coastal Wetlands: All types of hydrogeomorphic wetlands (lacustrine, riverine, barrier protected, plus sub-categories including estuaries and island coastal wetlands) with historic and current hydrologic connectivity to, and directly influenced by Lake Huron.
Nested feature examples: migrating waterbirds, eastern fox snake, northern pike.
Condition: FAIR – 13 indicators; 6 are at target, 7 are close to target

Coastal Terrestrial System: Shoreline up to 2 km inland or to the extent of the delineated Great Lakes coastal communities.
Nested feature examples: sand or cobble beaches, alvars, piping plover, Pitcher's thistle.
Condition: FAIR – 14 indicators; 10 are at target, 4 are close to target

Identifying Critical Threats

Direct threats to Lake Huron's biodiversity features were identified and ranked to determine which were most critical to maintaining and restoring ecological structure, function, and overall health. Expert input helped identify factors that are directly and negatively affecting biodiversity features. Threats were ranked according to scope, severity of impact, and irreversibility and those with broadest impact, across several features, ranked higher than others.

The most critical threats to Lake Huron's biodiversity were:
a) Non-native invasive aquatic and terrestrial species;
b) Housing and urban development, and shoreline alteration;
c) Climate change;
d) Dams and barriers; and
e) Agricultural, forestry and urban non-point source runoff.

GIS analysis illustrated the location of some of the threats. Some are difficult to map due to the nature of the phenomenon or lack of data (e.g. non-native invasive species, climate change).

Developing Conservation Strategies

Developing conservation strategies required a thorough understanding of how critical threats and their causal factors influence the health of biodiversity features. Conceptual models were created to visually illustrate a common understanding of how social, political, economic, and environmental elements act together to perpetuate direct and indirect threats to biodiversity features. This effort provided the foundation for identification and development of conservation strategies. Workshop participants identified specific conservation strategies, and how stakeholders and partners might play a role in implementation.

The Core Working Team summarized these strategies and conducted a review of related basin-wide reports and plans to reaffirm expert-identified strategies, identify any gaps, avoid duplication of effort, and promote and reinforce existing efforts. We selected 21 Priority Conservation Strategies that were determined by workshop participants to be most feasible and important to implement within the next 5 years (2011-2015). They are presented in the following table.

STRATEGY	THREAT(S) ABATED	SCALE OF IMPLEMENTATION
1. **LAND AND WATER PROTECTION STRATEGIES** – Land and water protection by governmental and non-governmental organizations represents a key conservation approach. It has been highly successful, but will become more important over time as the threats to Lake Huron become more pervasive.		
1.1 Effectively conserve a system of public and private conservation lands for coastal terrestrial, nearshore zone and island features that are resilient to changes in land use and climate.	Climate Change; Housing and Urban Development and Shoreline Alteration	Regional/Local
2. **LAND AND WATER MANAGEMENT STRATEGIES** – Conservation goals cannot be achieved with direct land and water protection alone. Therefore, strategies that address conservation needs across all lands and waters, whether managed for biodiversity or resource extraction outcomes, are essential. This suite of strategies is directed at achieving conservation goals on managed lands and waters.		
2.1 Implement an integrative approach to barrier management that accounts for ecological and social values.	Dams and Other Barriers	Lake Huron Basin-wide
2.2 Implement improved septic technologies, including conversion of targeted septic systems to municipal or communal sewage systems.	Non-point Source Pollution	Lake Huron Basin-wide
2.3 Implement targeted agricultural best management practices (BMPs) to address non-point source pollution impacts to Lake Huron biodiversity.	Non-point Source Pollution	Regional/Local
2.4 Develop and implement an integrative, adaptive, and harmonized framework for coastal management within selected US and Canadian geographic regions.	Housing and Urban Development and Shoreline Alteration	Regional/Local
2.5 Restore priority coastal terrestrial, nearshore zone and island features.	Housing and Urban Development and Shoreline Alteration	Regional/Local
2.6 Develop and implement programs that identify and conserve priority coastal terrestrial, nearshore zone and island habitats.	Housing and Urban Development and Shoreline Alteration	Lake Huron Basin-wide
3. **SPECIES MANAGEMENT STRATEGIES** – A comprehensive biodiversity conservation strategy must not only address ecological systems and processes, but also species management, especially for species that contribute to ecosystem and human health.		
3.1 Restore native populations of Lake Huron's aquatic and terrestrial species.	Non-native Invasive Species and other threats	Regional/Local
4. **EDUCATION AND AWARENESS STRATEGIES** – Effective conservation frequently relies on strategies that involve awareness and education of agencies, organizations, communities, and individuals, all of whom directly and indirectly benefit from a healthy Lake Huron ecosystem. Here we propose a suite of strategies designed to incorporate biodiversity values into resource management decisions.		
4.1 Enhance knowledge, technical skills and information exchange to build capacity of local policy and land use planning authorities to include biodiversity values into their decisions.	Housing and Urban Development and Shoreline Alteration	Regional/Local
4.2 Better educate the public on climate change issues: by creating credibility and a sense of urgency for climate change mitigation strategies being implemented across the basin, and by providing information about observed and expected climate changes effects in Lake Huron that is easily understood.	Climate change	Great Lakes Basin-wide
4.3 Increase community engagement, awareness, understanding and commitment to coastal terrestrial, nearshore zone and island conservation.	Housing and Urban Development and Shoreline Alteration	Regional/Local
5. **LAW AND POLICY STRATEGIES** – Biodiversity related legal mechanisms include law and policy strategies that address widespread threats that cross political boundaries. Below we highlight one highly ranked strategy to address a pervasive threat across the entire Great Lakes basin.		
5.1 Eliminate ballast water as a vector for invasive species introductions.	Non-native Invasive Species	Great Lakes Basin-wide
6. **LIVELIHOOD, ECONOMIC AND OTHER INCENTIVES STRATEGIES** – Biodiversity conservation is frequently more successful when livelihood and economic incentives are linked with strategy development. Here we propose a strategy recognizing conservation activities that acknowledge ecosystem services.		
6.1 Develop programs to provide economic incentives for protection or restoration of ecosystem services.	Non-point Source Pollution	Lake Huron Basin-wide
7. **EXTERNAL CAPACITY BUILDING STRATEGIES** – Two highly ranked strategies that address external capacity building highlight the need to address information management and invasive species management.		
7.1 Develop and implement a data and knowledge management system designed to guide future conservation actions and effectively track implementation efforts.	All	Great Lakes Basin-wide
7.2 Form early detection / rapid response teams to eradicate new invasive species before they become established.	Non-native Invasive Species	Lake Huron Basin-wide
8. RESEARCH STRATEGIES – While the conservation community of the Lake Huron basin has achieved tremendous success over the past decades, there still remain gaps in our basic scientific knowledge that limit our ability to implement a comprehensive biodiversity conservation strategy. Here we highlight a suite of strategies designed to fill such gaps.		
8.1 Establish a system for monitoring biodiversity and climate change in sentinel watershed sites.	Climate Change	Great Lakes Basin-wide
8.2 Assess the value of ecological goods and services provided by Lake Huron, including how values are altered under climate change scenarios.	Housing and Urban Development and Shoreline Alteration; Non-point Source Pollution; Climate Change	Great Lakes Basin-wide
8.3 Develop a Lake Huron-wide risk assessment that informs strategies for the prevention of invasive species.	Non-native Invasive Species	Lake Huron Basin-wide
8.4 Conduct place-based research and development of control techniques for non-native invasive species.	Non-native Invasive Species	Regional/Local
8.5 Conduct a comprehensive watershed assessment of key action areas for mitigation of agriculture, urban and forest non-point source pollution, with special regard for areas important to biodiversity features and areas where climate change is expected to exacerbate current problems.	Non-point Source Pollution; Climate Change	Lake Huron Basin-wide
8.6 Enhance research and monitoring of the nearshore zone and coastal terrestrial margin.	Strategy Housing and Urban Development and Shoreline Alteration	Great Lakes Basin-wide

Identifying Priority Areas

Effective biodiversity conservation requires the identification of priority areas or best bets to better focus limited resources. Three measures were used to determine priority areas for conservation: basin-wide ecological significance, ecological condition, and conservation capacity. A set of indicators for each factor were scored and the points added together to calculate an overall index that was displayed on maps with an eight natural break categories ranging from low to high. The final set of maps include basin-wide ecological significance for each of the four features, a basin-wide coastal development footprint map representing ecological condition, and a conservation capacity map. From the priority areas analysis, we have the following observations and recommendations:

1. While clear areas of biodiversity significance stand out for particular features, each subregion has significant biodiversity. In addition, the three sets of maps – biodiversity significance, condition and conservation capacity do not correlate. Thus the conservation challenge and Strategy implementation implications for Lake Huron are quite complex.
2. In some areas of high biodiversity significance (see Figure 8), application of land protection strategies is warranted. Biodiversity significance does not however take the goal of representation into account. Thus, we also need to include in a protection plan those areas of biodiversity significance in very developed areas.
3. The priority biodiversity conservation areas identified in this chapter are a subset of the areas where conservation action must be taken; many of the strategies described in Chapter 6 are threat abatement actions that may impact conservation targets from considerable distance.
4. Conservation capacity does not necessarily match the areas of highest biodiversity significance, thus we need to think beyond local conservation needs and consider how to best use those resources to abate human impacts that have a cumulative impact on the health of the whole lake ecosystem.
5. Information generated for this project can be used to identify and refine local and regional priorities for conservation actions.
6. We need to invest in inventory, classification, and analysis of the Nearshore Zone.

Conclusion

The maintenance and protection of the biological integrity of the Great Lakes is a cornerstone of the Great Lakes Water Quality Agreement. **The Lake Huron Biodiversity Conservation Strategy** represents a unifying vision to improve collaboration and advance integrated, cross-boundary ecosystem management for Lake Huron. It is the result of over two years of stakeholder consultation, solicitation of expert opinions, and integration of existing biodiversity conservation data, program goals, and objectives.

These efforts resulted in the identification of key biodiversity conservation features for planning and conservation focus, their current condition, critical threats and contributing factors, recommended actions to mitigate threats, and priority coastal regions and watersheds that should be the focus for implementation of protection activities. The LHBCS also provides a lakewide biodiversity context that will assist in land-use and conservation decisions, and serve to inform the general public of the importance of biodiversity conservation.

It is recognized that given the enormous scale and complexity of the Lake Huron basin, and the range of recommended biodiversity conservation strategies, the key to success lies in cooperative partnerships and stakeholder engagement throughout the basin. The strategies and actions outlined in this report are offered as a guide to the protection and restoration of Lake Huron's biodiversity.

How to Use this Strategy

The following are some suggestions for how the strategy content might be applied to help meet shared conservation goals.

- Review the actions within the Strategy to identify areas of synergy with the goals of your organization. Then use the Strategy to:
    - identify and refine local and regional priorities for conservation actions
    - justify applications to fund protection or restoration of native biodiversity
    - inform and educate watershed residents about what they can do to conserve biodiversity in their region
    - strengthen and enhance your local partnership network
- Incorporate actions from the Strategy into local and regional plans
- Refer to the technical report for consensus-driven principles and themes to guide implementation and monitoring
- Share this summary document with other Lake Huron stakeholders
- Recognize and encourage networks of organizations interested in biodiversity conservation
- Contact a member of the participating organizations to access GIS data to support mapping and planning in your local area
- Review the conceptual models of how threats operate on biodiversity features to identify areas for research

1. INTRODUCTION

1.1 The Sweetwater Sea

The earliest known inhabitants of the Lake Huron watershed were the Huron, five allied tribes that were part of the vast Iroquoian nation. With the first European encounter of Lake Huron by French explorers, not knowing of the other Great Lakes, they originally called it *"La Mer Douce,"* or "The Sweetwater Sea." But, in recognition of the aboriginal population, most early maps note Lake Huron with a label of "*Lac des Hurons*" ("Lake of the Hurons").

Lake Huron Facts

- Lake Huron is the 2nd largest Laurentian Great Lake by surface area (nearly 60,000 km^2) and 3rd largest by volume (3,500 km^3)
- By surface area, Lake Huron is the 5th largest lake globally
- Lake Huron's shoreline, including that of its 30,000 islands, is the longest among all the Great Lakes
- Retention time in Lake Huron is 22 years
- At more than 134,000 km^2, Lake Huron has the largest land drainage area among the Great Lakes, making the land-water connection even more acute here
- Georgian Bay (15,000 km^2) and Saginaw Bay (2,771 km^2) are the two largest bays on the Great Lakes
- Early explorers at first believed Georgian Bay to be a 6th Great Lake
- Manitoulin Island is the largest island in any freshwater system globally
- Thunder Bay National Marine Sanctuary, in northwest Lake Huron, is the Great Lakes' only National Marine Sanctuary (U.S. designation) and serves as an underwater museum of Great Lakes maritime heritage
- Fathom Five National Marine Park, at the tip of Bruce Peninsula, was Canada's first National Marine Conservation Area

Sources:
EPA and Environment Canada. 1995. Great Lakes Atlas, 3d Edition.
Great Lakes Information Network. "Lake Huron Facts and Figures."

Lake Huron is one of the five Laurentian Great Lakes, the world's largest freshwater ecosystem which contains several endemic species and natural communities found nowhere else on the planet. Lake Huron is actually four separate but interacting bodies of water: the North Channel, Georgian Bay, Saginaw Bay, and Lake Huron proper. Much of the northern coast and Georgian Bay is dominated by erosion-resistant igneous and metamorphic bedrock and this region contains extensive high quality coastal wetlands, and heavily forested habitats.

The southern basin consists of glacial deposits and eroded bedrock headlands that have been formed by glaciers, waves, currents and other coastal processes. The Niagara Escarpment is the most prominent geologic feature of the southern Lake Huron landscape; globally rare alvars are associated with this feature as are limestone cliffs, talus slopes, and the headwaters of several streams. These features support Great Lakes endemic species like Lakeside daisy and dwarf lake iris. The south is more urbanized and much of the "thumb" area of Michigan, Canada's Bruce Peninsula, and the southeast shore of the main basin is dominated by agriculture.

Lake Huron contains more islands than any other Great Lake; Manitoulin Island is the largest found anywhere in freshwater. Islands often harbor unique ecosystems due to their isolation, which can insulate them from some threats common to connected shorelines, allowing them to serve as refugia and creating different selection pressures for their inhabitants.

Historically, Lake Huron's geophysical diversity led to ecological diversity; while compromised in many places, the coasts have retained significant remnants of historic fish and wildlife habitat. Much of the coast is either rocky or has extensive wetlands, providing important microhabitats for species such as shore birds, softshell turtles, massasaugua rattlesnakes, and mayflies. Lake Huron's coastal areas also provides critical migratory bird stopover habitat, utilized by numerous species making long journeys along these important flyways. Nearshore aquatic ecosystems, together with coastal wetlands, are biodiversity hot spots and are the most productive places in Lake Huron.

The lake is home to many rare species - some endemic to the Great Lakes - such as the ebony boghunter, eastern pond mussel, mudpuppy, eastern fox snake, and piping plover, as well as recreationally important native fish such as walleye, smallmouth bass, northern pike, and yellow perch. Scientists recently discovered unusual sinkholes in the lake proper, which harbor life more reminiscent of ice-covered lakes in Antarctica than the biota elsewhere in the Great Lakes.

1.2 Why the Lake Huron Biodiversity Conservation Strategy?

Biological diversity, or ***biodiversity***, refers to the variety of life, as expressed through genes, species and ecosystems, and is shaped by ecological and evolutionary processes. The full spectrum of biodiversity is essential to maintaining the ecological functions, processes, and connections that sustain us and deliver many economic and social benefits.

While Lake Huron remains an ecologically rich and significant ecosystem, its biodiversity is at risk due to a number of stresses, including degradation of water quality, climate change, invasive species, rapid and poorly-planned residential and industrial growth, altered hydrology, and incompatible agricultural, fisheries, and forestry management and practices. Degradation and loss of historical habitat has been identified as a major stressor to Lake Huron and its watershed.

In 2002, the federal, state and provincial agencies that manage binational environmental activities under the Great Lakes Water Quality Agreement (GLWQA) formally endorsed the formation of a Lake Huron Binational Partnership in order to prioritize and coordinate environmental activities in the Lake Huron basin for the purposes of lakewide management planning. The federal and the state/provincial natural resource agencies form the core of the Partnership by providing leadership and coordination. However, the Partnership emphasizes the importance of having a flexible membership which is inclusive of other agencies and levels of government, Tribes/First Nations, non-government organizations, and the public on an issue by issue basis. To date, there has been no effort to systematically look at what is needed to protect and conserve the *native* biodiversity of Lake Huron. The LHBCS addresses this by determining the most critical needs on a lakewide basis. If implemented, the recommended strategies are collectively meant to restore and conserve a functioning ecosystem. By using this biodiversity ‘lens’ to synthesize, prioritize, and create synergies among past and ongoing related strategies, the LHBCS supports and advances a number of existing plans, initiatives, and agreements including the GLWQA; the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem; the Great Lakes Fishery Commission’s Fish-Community and Environmental Objectives for Lake Huron; Lake Huron-Georgian Bay Watershed Framework for Community Action; the Michigan Great Lakes Plan: Our Path to Protect, Restore, and Sustain Michigan’s Natural Treasures; and the Michigan Wildlife Action Plan.

1.3 Strategy Vision and Scope

The development of the LHBCS was bounded by our definition of vision and scope (for additional detail on how these were determined, see the following Chapter on the Conservation Action Planning Process; see Appendix A for a glossary of these and other new terms introduced throughout the technical report).

Strategy Vision

Maintain and restore the viability of native plant and animal communities of Lake Huron by conserving the habitats and processes that sustain them so that all may benefit from their values now and in the future.

Strategy Scope

The LHBCS focuses on the conservation of the native biodiversity of Lake Huron, represented by selected *biodiversity features*, and is limited geographically to the lake, St. Marys River connecting channel, and coastal areas. However, threats to these biodiversity features and the conservation actions needed to abate the threats may originate from within the lake or from inland areas in the basin; some may even occur outside of the basin. Therefore, scope (Figure 1) is dually defined as:

Biodiversity features scope: *Lake Huron and associated nearshore and aquatic habitats. This scope focuses on what biological diversity we are trying to conserve.*

Planning region scope: *Lake Huron basin. This scope focuses on the geographic area that may impact the biological diversity of interest.*

1.4 Addressing Regional Heterogeneity

Planning at broad scales can present some challenges; Lake Huron has considerable regional differences, both ecologically and in terms of landscape context, that can be masked by assessing the lake's biodiversity as a single entity. The most striking variation can be observed along the north-south gradient. Northern portions of the watershed, including Georgian Bay, tend to have lower population density and are largely forested; meanwhile, southern portions have higher population densities, more urban centers, and more agricultural and industrial activities. This results in a higher degree of ecological degradation and additional challenges to natural resource management in southern Lake Huron. Where sufficient information was available, we considered the north-south variation or even finer scale stratifications while assessing status, threats, and conservation needs.

1.5 Orientation to the Strategy

A Steering Committee with representation from key agencies and organizations from Canada, the United States, and First Nations, Tribal, and Métis groups guided the development of the Strategy (see Appendix B). The Nature Conservancy (TNC), Michigan Sea Grant (MSG), and Michigan Natural Features Inventory (MNFI) were awarded funding to serve as the U.S. Co-Principal Investigators; the Michigan Department of Natural Resources and Environment (MDNRE) also contributed staff to serve in this role. Counterparts on the Canadian side included Environment Canada (EC), Ontario Ministry of Natural Resources (OMNR), and Nature Conservancy of Canada (NCC).

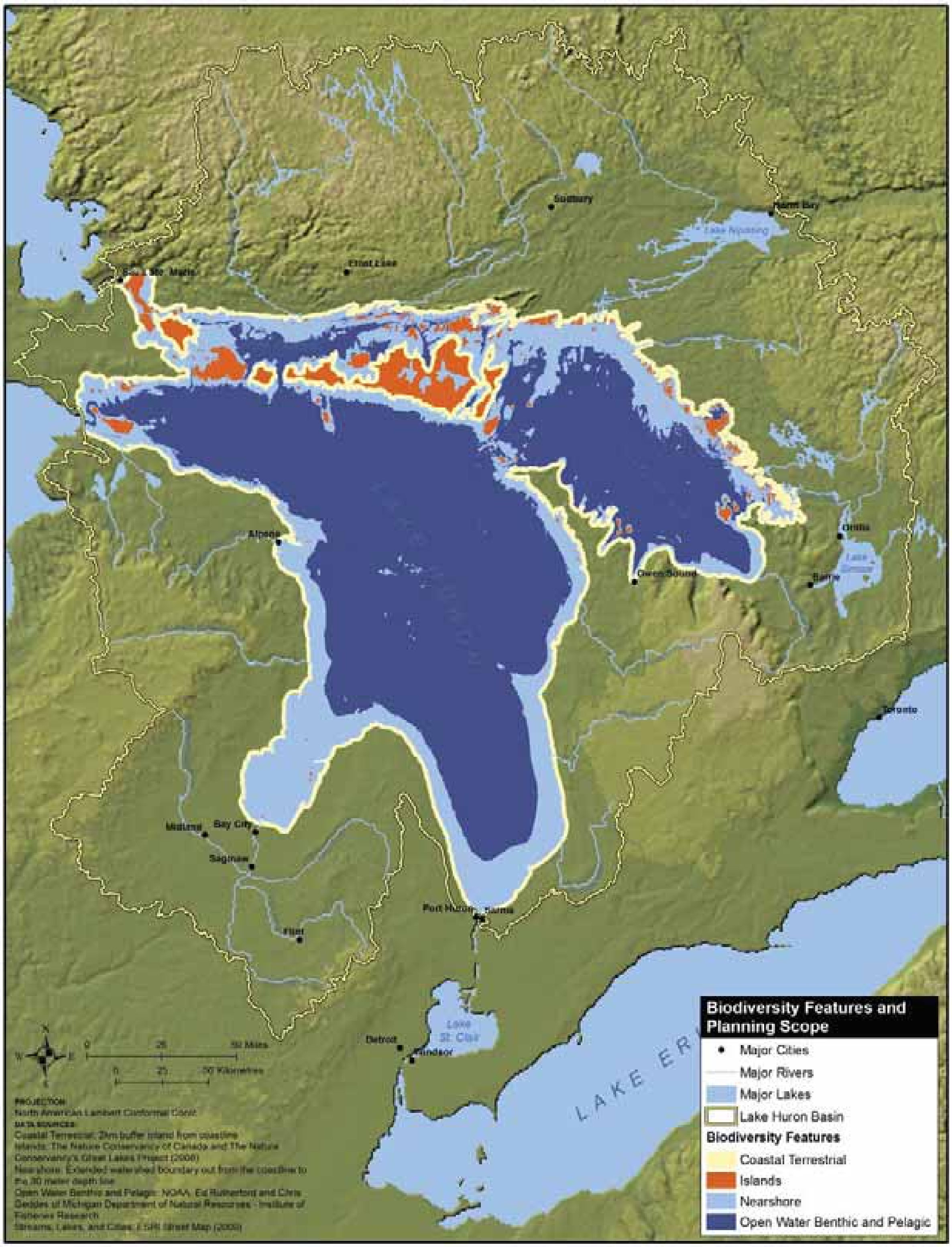

Figure 1: Lake Huron Biodiversity Conservation Strategy Project Scope.

The LHBCS was developed by a wide-range of partners from around the lake. This systematic process identified which biodiversity features collectively represent the full suite of Lake Huron's biodiversity, the most serious threats to biodiversity, and what actions are needed to abate those threats, and/or to maintain and improve the viability of the biodiversity features. This effort also relied on the analysis of spatial data to identify important places to focus on-the-ground efforts. Two products were produced to document the LHBCS. This document, *The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron - Technical Report*, details the entire process and results of the development of the Strategy. A brief, action-oriented document, *The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron,* was also produced to succinctly put the substance of the Strategy and priority biodiversity conservation areas in the hands of decision makers and implementers; this abridged document outlines the fundamental needs to protect, sustain, and restore the biodiversity of Lake Huron.

In this *Technical Report*, we provide more detailed information about the various steps in the development of the Lake Huron Biodiversity Conservation Strategy. The **Conservation Action Planning Process** chapter describes the planning process and broad stakeholder participation used to develop the Strategy. The **Biodiversity Features** and **Viability Assessment of Biodiversity Features** chapters provide detailed description and assessment of condition of each of the biodiversity features selected to represent the full suite of Lake Huron biodiversity. The **Threats Assessment** chapter provides an overview and rating of all the stresses on Lake Huron biodiversity, and goes in-depth on the five most critical threats by describing how each degrades the biodiversity features and by identifying the factors that contribute to this degradation. The **Strategies** chapter outlines necessary actions at multiple scales for abating critical threats to and improving condition of Lake Huron biodiversity. The **Priority Biodiversity Conservation Areas** chapter identifies those locations of highest biodiversity value. Finally, the **Next Steps: Implementing Strategies and Tracking Progress** chapter outlines some of the practical measures that should be taken to implement the LHBCS recommendations and serves as a '**Call to Action**' for those with care and concern for Lake Huron.

Looking for Additional Information about Lake Huron?

In developing the Lake Huron Biodiversity Conservation Strategy, we have not summarized the full suite of significant, interesting, and increasing information available on Lake Huron; others have and continue to do so! If you would like to learn more, we recommend the following references and weblinks:

- Dennis, Jerry. 2004. *The Living Great Lakes: Searching for the Heart of the Inland Seas*. St. Marten's Griffin.
- EPA and Environment Canada. 1995. The Great Lakes: An Environmental Atlas and Resource Book, 3d Ed.
- EPA and Environment Canada. 1994-Ongoing. State of the Lake Ecosystem Conference Reports, various.
- Great Lakes Information Network's Lake Huron Facts and Figures Website.
- Hough, Jack. 1958. *Geology of the Great Lakes*. University of Illinois Press.
- Journal of Great Lakes Research, various articles (including an upcoming special edition on Lake Huron).
- Shelton, Napier. 1999. *Huron: The Seasons of a Great Lake*. Wayne State University Press.

2. THE CONSERVATION ACTION PLANNING PROCESS

The Nature Conservancy's ***Conservation Action Planning (CAP)*** process was used to develop the Lake Huron Biodiversity Conservation Strategy (Figure 2; TNC 2007). The CAP process is a proven approach for planning, implementing, and measuring success for conservation projects. This chapter describes the process for developing the Strategy.

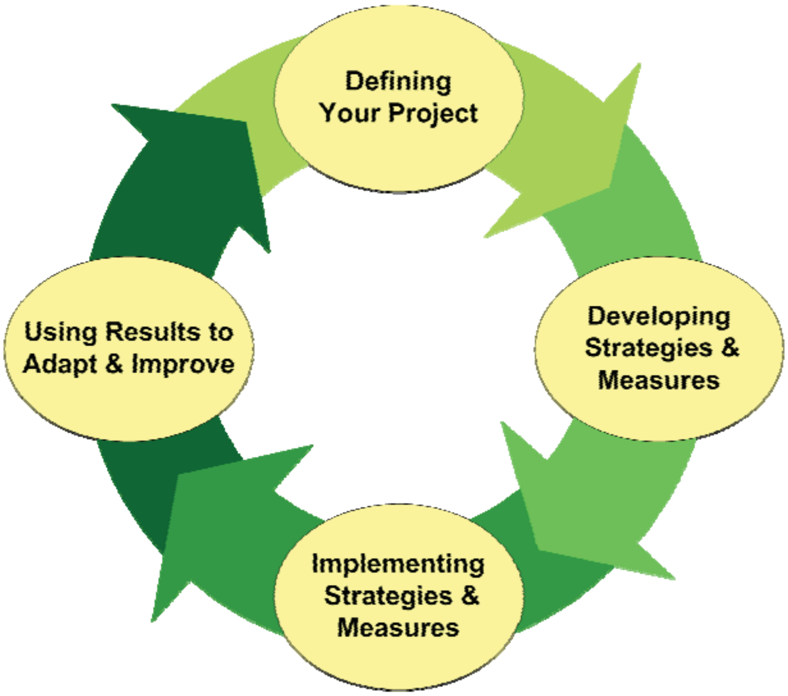

Figure 2: The Conservation Action Planning Process.

2.1 Project Coordination

To ensure cooperation and coordination across boundaries and agencies, this project was guided by an international Steering Committee and managed by a Core Team. The Core Team developed and facilitated the process, and produced the final reports; this group consisted of individuals from Environment Canada, Ontario Ministry of Natural Resources, Michigan Department of Natural Resources and Environment, The Nature Conservancy, Michigan Sea Grant, Nature Conservancy of Canada, and Michigan Natural Features Inventory. The Steering Committee consulted on the process, partner involvement, and content. It included representatives from the following organizations: U.S. Environmental Protection Agency-Great Lakes National Program Office, Ontario Ministry of Agriculture, Food and Rural Affairs, Ontario Ministry of the Environment, Conservation Ontario, Parks Canada, Michigan Department of Agriculture, Anishinabek Nation, Métis Nation of Ontario, Chippewa/Ottawa Resource Authority, and all entities that participate in the Core Team (Appendix B). To aid in facilitating the workshops and the CAP process, Foundations of Success, a private consulting firm with global experience and expertise in leading CAP development, was retained.

Project coordination was conducted by emails, conference calls, web conferencing tools, and in-person meetings.

2.2 Overview of CAP Process

Conservation Action Planning (CAP) is a process that assists project teams in developing the most effective conservation strategies based on the best available scientific information (Figure 2; TNC 2007). Many CAPs incorporate that scientific information through an expert-driven process; such is the case for the LHBCS, during which we also consulted and incorporated seminal scientific references, but derived most content from expert participation (see 2.3 Stakeholder and Partner Engagement).

The CAP process also facilitates adaptive management through the identification of explicit measures of success and incorporation of lessons learned. The LHBCS team included many experienced CAP practitioners and benefitted from professional CAP facilitators. The CAP process is scale independent—it can be applied to small sites and large landscapes—but has rarely been applied to a geography as large as a Great Lake, so the Core Team was fortunate to incorporate experience gained from the recent development of the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009), for which CAP was also used. The CAP process is designed to help conservation practitioners:

- identify and assess the health or viability of biodiversity features
- identify and rank threats to biodiversity features,
- develop strategies to abate the most critical threats and enhance the health of the biodiversity features, and
- identify measures for tracking project success.

> **Biodiversity Features:** Specific species, Natural Communities, and ecological natural systems chosen to represent the overall biodiversity of the project area.
>
> **Key Ecological Attribute (KEAs):** Aspects of a biodiversity feature's biology or ecology that, if missing or altered, would lead to the loss of that feature over time.

The CAP process includes four main stages: Defining Your Project, Developing Strategies & Measures, Implementing Strategies & Measures, and Using Results to Adapt & Improve (Figure 2). This process clarifies the linkages between specific conservation actions and changes in Lake Huron ecosystem health over time. For a complete list of definitions see Appendix A.

2.2a Defining the Project

The CAP process starts with Defining Your Project (TNC 2007). Project participants are identified including the project team, advisors or steering committee members, and stakeholders. The project scope is defined both conceptually and spatially. In this step, the team defined the area that provided the biodiversity of interest and from which threats to biodiversity could originate. ***Biodiversity features*** were explicitly defined and selected for their ability to represent the full suite of biodiversity within the project area, including its species, natural communities, and ecological systems. Effective conservation of carefully selected biodiversity features will ensure the conservation of all native biodiversity within functional landscapes.

2.2b Developing Strategies & Measures

Developing Strategies & Measures consists of four main steps: assessing viability of biodiversity features, identifying critical threats, developing conservation strategies, and establishing measures.

Assessing Viability

Assessing ***viability*** entails evaluating the current "health" status and desired future status of each biodiversity feature. For each biodiversity feature, the team determined how to measure its viability. An important part of this process was to define the ***key ecological attributes (KEAs)*** and indicators of each biodiversity feature. Key Ecological Attributes include size (or abundance), condition (measure of biological composition, structure, and biotic interactions), and landscape context (assessment of the environment and ecological processes that maintain the biodiversity feature). To accompany the range in viability of the biodiversity features, spatial information was analyzed using Geographic Information Systems (GIS) to provide more specific information on the health of the features in different regions of the project area.

Expected Outputs of the Viability Assessment (TNC 2007): The final output is an assessment of the overall viability for each feature based on KEAs. The components of this overall assessment include:

- At least one KEA for each feature.
- A measurable indicator for each KEA (in some cases, the indicator may be the same as the attribute itself).
- Best available information as to what constitutes an acceptable range of variation for each KEA.
- Current and desired future status of each KEA.
- Brief documentation of how you arrived at your viability assessments including references, experts consulted, assumptions, and suggested research needs.

Identifying Critical Threats

Working groups identified the various factors that directly and negatively affect the selected biodiversity features. Working groups then ranked the ***critical threats*** according to the scope and severity of their impacts and the difficulty of reversing their effects on the features. The threat ranks are then amalgamated across all biodiversity features, and those that have the highest overall rank form the subset of critical threats, the ones on which most conservation efforts should be focused. GIS was also used to identify geographic variability for some threats.

Developing Conservation Strategies

Developing conservation strategies required a thorough understanding of how critical threats affect the biodiversity features, and the viability of the biodiversity features. Detailed ***conceptual models*** of the teams' understanding of both the biological issues and the human context as they relate to each critical threat were created. This was done by conducting a ***situation analysis*** for each critical threat to identify factors that influence perpetuation of a threat or that may represent opportunities to abate a threat. This effort provided the foundation for identification and development of ***conservation strategies***. Specific conservation strategies were identified along with the direct and indirect threats they address. Strategies were ranked, and those strategies that were anticipated to be the most effective and feasible were further detailed with goals and objectives.

Establishing Measures

Establishing ***measures*** and creating a monitoring plan are critical to determining success of the conservation strategies. Measuring both the effectiveness of strategies (process) and status of the biodiversity features (outcomes) is needed for effective adaptive management.

Implementing Strategies and Measures

Implementing strategies and measures is the next step after the strategic goals and actions are detailed. This involves including strategic goals and actions into work plans of organizations. This part of the CAP process is beyond the scope of this project and will be taken on by conservation practitioners immediately and in years to come (see Chapter 8: Next Steps).

Using Results to Adapt and Improve

Once implementation has begun, it is critical to systematically evaluate the actions that are implemented, to update and refine the current knowledge of the biodiversity features, and to review the results available from monitoring efforts. This last step represents the feedback loop required for adaptive management, such that as we learn more and the ecosystem responds, practices and actions are adapted to be most effective in response to these changing circumstances. Again, this part of the CAP process is beyond the scope of this project, but the measures identified here should prove useful to the process.

2.3 Stakeholder and Partner Engagement

The Core Team provided a variety of opportunities for organizations and individuals to contribute to the LHBCS. We held workshops, hosted telephone and web conference calls, conducted on-line surveys, and held small meetings to gather contributions and review of the LHBCS. The LHBCS is the product of a large group of individuals from many agencies and organizations who are concerned about and responsible for safeguarding the health and sustainability of Lake Huron and its biodiversity.

2.3a Workshops

The first LHBCS workshop (Workshop I) was held in Port Huron, Michigan on December 10th and 11th, 2008 and was attended by 57 participants representing 35 agencies and organizations (Appendix B). Participants were invited to attend this workshop based on their expertise and knowledge of the ecological systems and species of Lake Huron. The outcomes from this workshop were final drafts of the vision and scope of the Strategy, and the final draft of the biodiversity features that were used to represent and encompass the full array of biodiversity in Lake Huron for the LHBCS. Identification and ranking of critical threats to and viability assessments of the biodiversity features were also started at the workshop, and later refined with feature-based expert review (see below).

The second LHBCS workshop (Workshop II) was held in Sarnia, Ontario on March 30th and 31st, 2009 and was attended by 62 participants representing many sectors from both the U.S. and Canada, including policy, management, and scientific experts from all levels of government, tribes/First Nations, academic institutions, businesses, and non-profit organizations (Appendix B). This workshop focused on developing conceptual models and conservation strategies for the highest-rated critical threats, some of which were combined to better facilitate discussions. Participants self-selected into one of the five break-out groups, which focused on 1) aquatic and terrestrial invasive non-native species, 2) housing and urban development and shoreline alterations, 3) dams and other barriers, 4) agricultural, forestry and urban non-point pollution, and 5) climate change. The outcomes from this workshop were draft conceptual models of each of the five critical threats and a draft list of strategies to abate each threat.

The third LHBCS workshop (Workshop III) was held in November 9th and 10th, 2009 and was attended by 43 participants representing 29 agencies and organizations (Appendix B). This workshop focused on prioritizing conservation strategies and then further developing the most feasible conservation strategies by identifying goals, objectives, and actions. The outcomes from this workshop were final draft prioritized conservation strategies with detailed goals, objectives, and actions.

2.3b Working Groups

Throughout the development of the LHBCS we relied on working groups to continue the work that was started at the workshops. For example, the viability assessments were introduced in Workshop I, but the work of determining viability of biodiversity features occurred through small working groups meeting in person, through web conferencing, or communicating by phone or email. These groups included individuals from a variety of organizations and often included Core Team members, participants from workshops, as well as additional participants where relevant. These working groups contributed the bulk of the content and scientific credibility and validation for the LHBCS. For a list of participants in the different working groups see Appendix B.

2.3c Regional Workshops

Seven regional workshops were held near the end of the LHBCS process to create an opportunity to present and vet findings with more local partners and stakeholders. Workshops were held in December 2009 in Elmwood, Espanola, and Parry Sound, Ontario and in February 2010 in Bad Axe, Bay City, Alpena, and St. Ignace, Michigan. In addition, a workshop was held in Sudbury, Ontario in March 2010 for aboriginal groups. These workshops provided a mechanism to gather input and review of the priority areas maps. These groups also identified strategies pertinent to specific places around the lake and actions, including those already underway, to make the Strategy more relevant, tangible, and implementable at more localized scales. For a list of participants at the regional workshops see Appendix B.

2.3d Other Input Opportunities

Throughout the development of the LHBCS, the Core Team provided a variety of other ways for stakeholders and partners to be involved. Initially, an electronic survey was conducted to gather input on biodiversity features to feed into Workshop I. Quarterly emails went out to all participants (over 350 individuals) to: provide progress reports, provide summaries of the outcomes from each workshop and ask for review, and alert stakeholders of opportunities to provide specific input on draft products, such as the draft list of biodiversity features. An internet work space (http://conserveonline.org/workspaces/lakehuron.bcs) was established to serve as a repository for draft documents and to allow stakeholders and partners to easily track the project's progress. The Core Team also held meetings using web conferencing tools to provide an orientation and background information for workshop participants to prepare for the workshops, to get critiques of the draft proposed methodology for priority areas, and to vet draft strategies.

3. BIODIVERSITY FEATURES

3.1 Identification of Biodiversity Features

As is more fully described in Chapter 2, the set of biodiversity features for Lake Huron was selected to represent the full biodiversity of the lake. The features range in scale from ecological systems to individual species, and the final list is the result of a consensus process involving well over 100 participants. First, the core team and steering committee developed a draft list of **biodiversity features** and **nested features**, drawing in part from similar CAP processes in Lake Ontario and local areas around Lake Huron, as well as other biodiversity and natural resource plans focused on Lake Huron. Prior to Workshop I, a survey including this draft list was sent to over 350 individuals from a variety of management and regulatory agencies, conservation organizations, academic institutions, tribes, First Nations, units of government and others for input. The results from the 127 respondents of this survey provided the basis for an exercise in Workshop I that resulted in the final list of seven biodiversity features. The exercise started with participants working in groups of four to select eight biodiversity features thought to represent the full array of biodiversity for Lake Huron. Participant groups were combined into successively larger groups and at each stage the groups were asked to come up with a common eight biodiversity features. With four groups remaining, all participants came together to discuss the results and work towards a consensus list of seven biodiversity features to represent the overall biodiversity of Lake Huron. Discussion of each feature enabled common understanding of what each feature represented. Participants rated this exercise as one of the most effective in the workshop.

> **Biodiversity features:** Specific species, Natural Communities, and ecological natural systems chosen to represent the overall biodiversity of the project area.
>
> **Nested features:** Species, Natural Communities, or ecosystems whose conservation needs are subsumed in one or more biodiversity feature.

Once the biodiversity features were generally agreed upon, participants separated into workgroups to further refine the name and definition of each biodiversity feature and to detail nested features.

3.2 Summary of Biodiversity Features

Each biodiversity feature is defined below, along with its nested features. More complete descriptions of each feature appear in Chapter 4.

Open Water Benthic and Pelagic Ecosystem (Open Water Ecosystem): Open water ecosystem beyond the 30-meter bathymetric contour from the mainland or islands, including reefs and shoals (Figure 3).

Nested features include: benthic invertebrates (e.g., *Diporeia*), forage fishes (benthic and pelagic), fish and bird piscivores (benthic, pelagic, avian), shoals and reefs, phytoplankton.

Nearshore Zone: Submerged lands and water column of Lake Huron starting at 0 meters (shoreline) and extending to 30 meters in depth, not including areas upstream from river mouths and riverine coastal wetlands.

Nested features include: native submerged aquatic vegetation, shore birds, waterfowl, map turtles, musk turtles, snapping turtles, softshell turtles, benthic macroinvertebrates (e.g., *Hexagenia*), smallmouth bass, walleye, yellow perch, lake herring, lake sturgeon, and spawning habitat for offshore fishes.

Islands: Land masses within Lake Huron that are surrounded by water, including both naturally formed and artificial islands that are 'naturalized' or support nested targets.

Nested features include: colonial nesting waterbirds, globally rare species, natural communities, and ecological systems, and migratory bird stopover habitat.

Native Migratory Fish: Native fish that migrate to and depend on tributaries, nearshore areas, or wetlands as part of their natural life cycles.

Nested features include: lake sturgeon, walleye, lake trout, coaster brook trout, suckers and redhorse, pike (including muskellunge), burbot, native lamprey, and yellow perch.

Coastal Wetlands: All types of hydrogeomorphic wetlands (lacustrine, riverine, barrier protected, plus sub-categories including estuaries and island coastal wetlands) with historic and current hydrologic connectivity to, and directly influenced by Lake Huron.

Nested features include: emergent marshes, wet meadows, sedge communities, fens, migratory waterbirds, wetland obligate nesting birds, eastern fox snake, queen snake, submergent/emergent/floating native aquatic plants, all escocids, other wetland dependent fishes, and aquatic macroinvertebrates.

Coastal Terrestrial System: Shoreline up to 2 km inland or to the extent of the delineated Great Lakes coastal communities.

Nested features include: mainland dune and beach ecosystems, shoreline cliffs and bluffs, Atlantic coastal plain disjunct communities, coastal alvars, dune and swale complexes, lake plain prairies, coastal forests, karst-associated communities, coastal fens, coastal rock barrens, migratory stopover sites for shorebirds and landbirds, coastal grasslands, piping plover, Pitcher's thistle, and Hill's thistle.

Aerial Migrants: Migrants that have high fidelity to Lake Huron, and for which migratory corridors associated with the lake are crucial to their survival.

Nested features include: all types of migratory birds, bats, butterflies, and dragonflies.

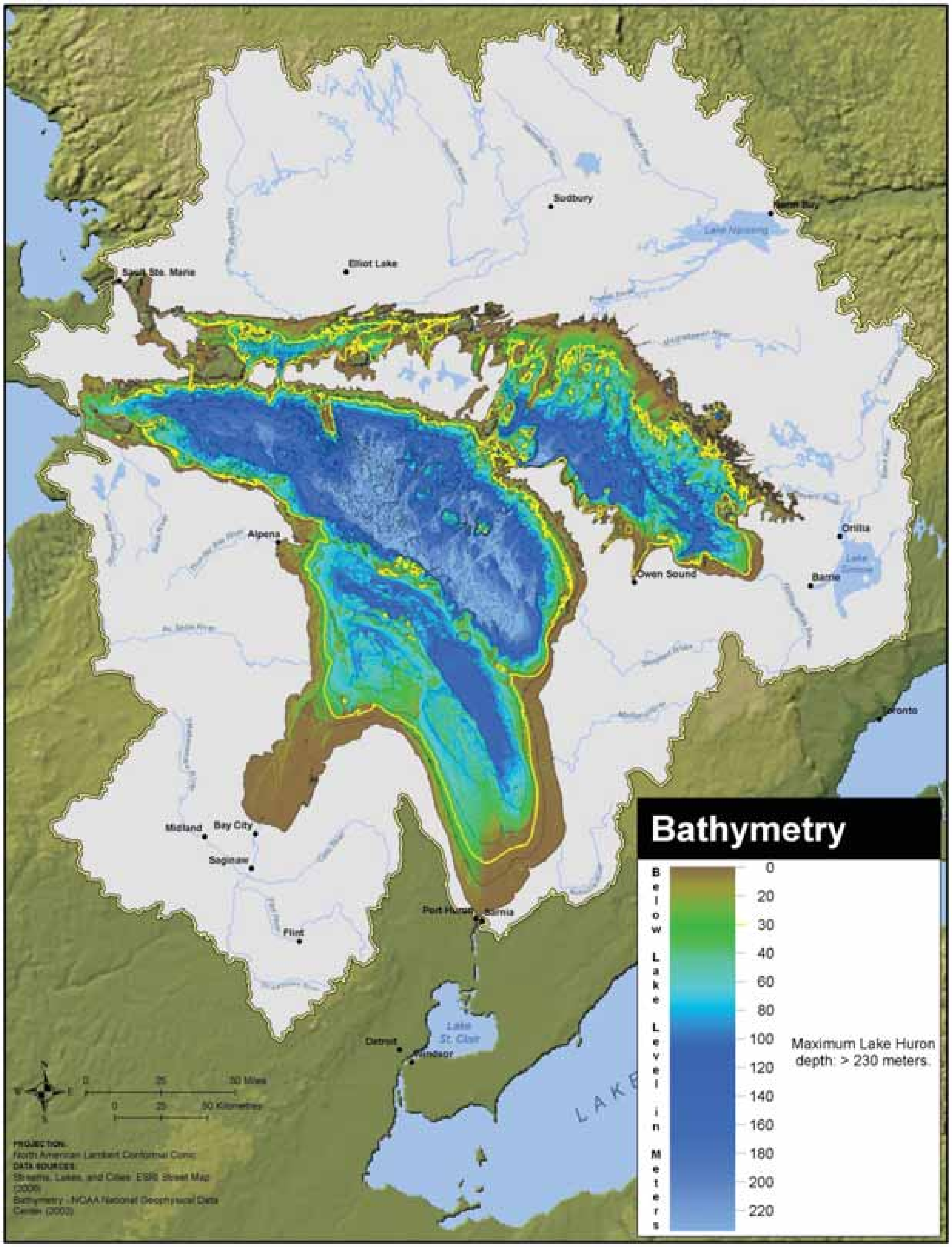

Figure 3: Lake Huron Bathymetry. The 30-m contour is highlighted, showing the delineation between the Open Water Benthic and Pelagic biodiversity feature and the Nearshore Zone biodiversity feature.

4. VIABILITY ASSESSMENT OF BIODIVERSITY FEATURES

This chapter presents an assessment of the current condition (health or viability) of Lake Huron and each of the biodiversity features included in this Strategy. Key Ecological Attributes (KEAs) and indicators were determined for each biodiversity feature, each of which were reviewed and evaluated by a working group of experts. Work groups also developed suggestions for desired condition of those indicators, essentially articulating a composite goal for maintenance or recovery of viability.

Most KEAs and indicators are unique to one biodiversity feature, but some KEAs are important to many of the biodiversity features and appear repeatedly in this assessment. One of these, water level fluctuations, affects the Nearshore Zone, Coastal Wetlands, and Coastal Terrestrial System features in profound ways. Water level variability is one of the primary drivers of biodiversity in coastal ecosystems (Burton et al. 2004, Albert et al. 2005, Wilcox et al. 2002, Minns et al. 1994) and the life stages of many native species are linked to the natural range and variability of Lake Huron water levels. Biota, however, are also influenced by antecedent conditions, biogeography, climate, weather events, and anthropogenic stresses to those habitats, such as non-point and point source pollution, invasive species, and landscape influences (Ciborowski and Niemi 2008). The dynamics of water level fluctuations create and maintain plant zonation, which in turn creates specific chemical and physical gradients within Coastal Wetlands. Hence, distinguishing between both direct and indirect effects of water level fluctuations on performance indicators is essential.

The International Upper Great Lakes Study is investigating current and potential water regulation plans at the St. Marys River water control structure. An Ecosystem Technical Working group has developed a study approach with objectives to “minimize adverse impacts to biotic communities and ecosystem functions by maintaining water level regimes that support diverse biotic communities and ecosystem functions in the Upper Great Lakes.” A set of ecosystem components and performance indicators, quite similar to the KEAs and indicators used in this assessment, are being developed and will be monitored at locations around the basin. These performance indicators are intended to be site-specific in application (G. Mayne pers comm.), but as they become finalized, they should be evaluated for incorporation into this lakewide viability assessment.

In this chapter, we describe the overall viability of Lake Huron, which is derived by aggregating the assessments of the biodiversity features. Viability assessments for each of the features, including general descriptions of the features, follow the overall summary. This chapter only details those indicators for which thresholds and/or status was assessed; recommended indicators that lacked sufficient data for assessment are provided in Appendix C. Future survey and monitoring efforts, such as those focusing on Coastal Wetlands that will be funded through the Great Lakes Restoration Initiative, should lead to improved viability assessments in coming years.

4.1 Methodology

At Workshop I, working groups were formed to focus on each biodiversity feature to assess viability and identify threats to their structure, function, and persistence. These working groups continued to refine the viability assessments through periodic conference calls and web conferences, and determined the Key Ecological Attributes (KEAs, i.e., critical components) of each selected biodiversity feature and thresholds for condition to aid in determining each feature’s viability. These working groups continued with identifying direct threats affecting biodiversity features and ranking the severity of those threats.

For each KEA, the working groups identified indicators that provide the basis for ratings of status: POOR, FAIR, GOOD, or VERY GOOD, based on the best available information—definitions for the viability ratings appear in Table 1. Indicator ratings are usually quantitative but, can be qualitative when relationships between an indicator and the viability of a biodiversity feature are poorly understood or information is lacking.

Completing the viability assessment of an ecological system as large as Lake Huron presented multiple challenges, many of which are simply due to the size of the lake and its watershed. Though there are perhaps hundreds of scientists researching the aquatic and coastal ecosystems, plant and animal communities, and climatic and hydrologic processes of Lake Huron, data for many of the biodiversity features are incomplete or, for particular indicators, entirely lacking (Environment Canada and U.S. EPA 2007). This assessment thus relies heavily on the experience and knowledge of groups of experts and the ratings and current status of many indicators are not based on published data. To bolster this approach, the viability assessment has been subject to broad review by other experts and stakeholders, and though not perfect represents a credible first iteration.

Geographic variation across the lake in depth, geology, substrate, bathymetry, shoreline configuration, and regional climate also results in significant regional differences in plant and animal communities, confounding the definition of biodiversity features and the selection and evaluation of KEAs and indicators. For example, coastal marshes not only can be categorized by hydrogeomorphic type, they also vary in plant and animal composition from north to south and among geographic regions (e.g., Georgian Bay). Recognizing these limitations, completing a lakewide viability assessment provides a basis for tracking gains or losses at a broad scale and is a valuable tool.

Table 1: Descriptions of viability ratings used in the CAP process (TNC 2007).

Very Good	The indicator is functioning at an ecologically desirable status and requires little human intervention.
Good	The indicator is functioning within its acceptable range of variation; it may require some human intervention.
Fair	The indicator lies outside its acceptable range of variation and requires human intervention. If unchecked, the target will be vulnerable to serious degradation.
Poor	Allowing the indicator to remain in this condition for an extended period will make restoration or preventing extirpation practically impossible.

To meet the challenge of geographic variability, we employed two tactics. First, working groups for some features applied a geographic stratification to the viability assessment. In this approach, indicators for appropriate KEAs were evaluated separately for each geographic stratification unit (Table 2). Stratification resulted in an expansion of the overall number of indicators, which was seen as preferable to increasing the number of biodiversity features.

The second tactic to account for geographic variability involved mapping the status of selected indicators. These maps were used both in the viability assessment and in the identification of Priority Biodiversity Conservation Areas (see Chapter 7).

Table 2: Stratification of viability assessments for each biodiversity feature.

Feature	Stratification
Open Water Benthic and Pelagic Ecosystem	Whole Lake (not stratified)
Nearshore Zone	Whole Lake (not stratified) for open water indicators; Northern/Southern Lake Huron[1] for coastal indicators (see Figure 4)
Islands	Whole Lake (not stratified)
Native Migratory Fish	Five Basins: Georgian Bay Main Basin North Channel Saginaw Bay St. Marys River
Coastal Wetlands	Northern/ Southern Lake Huron
Coastal Terrestrial System	Northern/ Southern Lake Huron
Aerial Migrants	Northern/Southern Lake Huron

To evaluate indicators for which data were lacking, working groups relied on expert knowledge or familiarity with the biodiversity features. In some cases, teams identified indicators that lack data and for which no references could be located. For example: habitat for migrating bats within the Aerial Migrants feature and lake levels. Currently data do not exist and analysis on thresholds is in progress, respectively. These and other indicators that are recommended for future survey and monitoring but that could not currently be assessed are presented in Appendix C.

A final challenge to working groups stems from the dramatic changes that have occurred in and around Lake Huron over the last two or more centuries. The lake and its surrounding watershed have undergone substantial changes: the southern portion of the watershed (and some of the northern portion) have seen wide-scale conversion of forests to agriculture and other land uses; soils that were once held in place by native plants now erode much more easily in converted lands; tributary streams have been dammed, crossed by roads, or constricted by culverts, causing interruptions in the life cycle of Native Migratory Fish; Coastal Wetlands and natural beaches have been diked or hardened; and connecting channels that determine inflows and outflows have been dredged or controlled. Partly resulting from these alterations to the physical structure and ecological processes of the lake, some formerly abundant species have been extirpated, or nearly so; introduced species have become highly abundant and, in some cases, subsequently experienced population crashes; and the life cycles of native species have been significantly altered. As one example, prior to the mid-19th century, there were very high densities of very old and very large fish. Lake trout reached 30 kg or more, lake sturgeon sometimes exceeded 100 kg and lake herring (now almost extirpated) were ubiquitous (Trautman 1957). Lake herring spawning bouts would result in windrows of eggs covering the shore to a depth of several feet. Recruitment of young fish was low, relative to present recruitment rates,

[1] The division between Northern and Southern Lake Huron is defined in the U.S. as the line between the Midwest Broadleaf Forest (Province 222) and the Laurentian Mixed Forest (Province 212) of the Ecoregions of the United States (Cleland et al. 2007) and in Canada as the line between the Mixedwood Plains and Boreal Shield Ecozones of the National Ecological Framework for Canada (http://www.ec.gc.ca/soer-ree/English/Framework/Nardesc/canada_e.cfm accessed 11 September 2009). This division is based on a major transition in climate and terrestrial vegetation and is reflected in land use patterns.

because there were so many predators, but most fish species had long life spans. Turnover of fish biomass was also relatively low; current harvest rates and higher mortality has resulted in much greater turnover of biomass and allows relatively greater recruitment of young fish.

Restoration of the open water, nearshore, wetland and terrestrial systems of Lake Huron is a primary goal of many agencies and organizations. Restoration often is based on reference conditions that occurred at some point in the past or some other similar but less altered ecosystem. The Great Lakes are each unique, and given past changes, uncertainty about the impacts of ongoing climatic change, and the multiple, sometimes conflicting demands on the lake and its resources, there is no place or past time that serves as a practical reference. Recognizing these constraints, experts in each of the working groups used the most current information and their own best judgment to select and assess the KEAs and indicators presented here. They represent, in collective form, a multi-faceted goal for the restoration of the biodiversity features of Lake Huron. The “desired future status”, typically given by the rating for GOOD or VERY GOOD for each indicator, represents the best and most feasible status to which each indicator might be elevated. These ratings do not necessarily match any particular reference point but may be considered, collectively, a reasonable goal for restoration of biodiversity in Lake Huron.

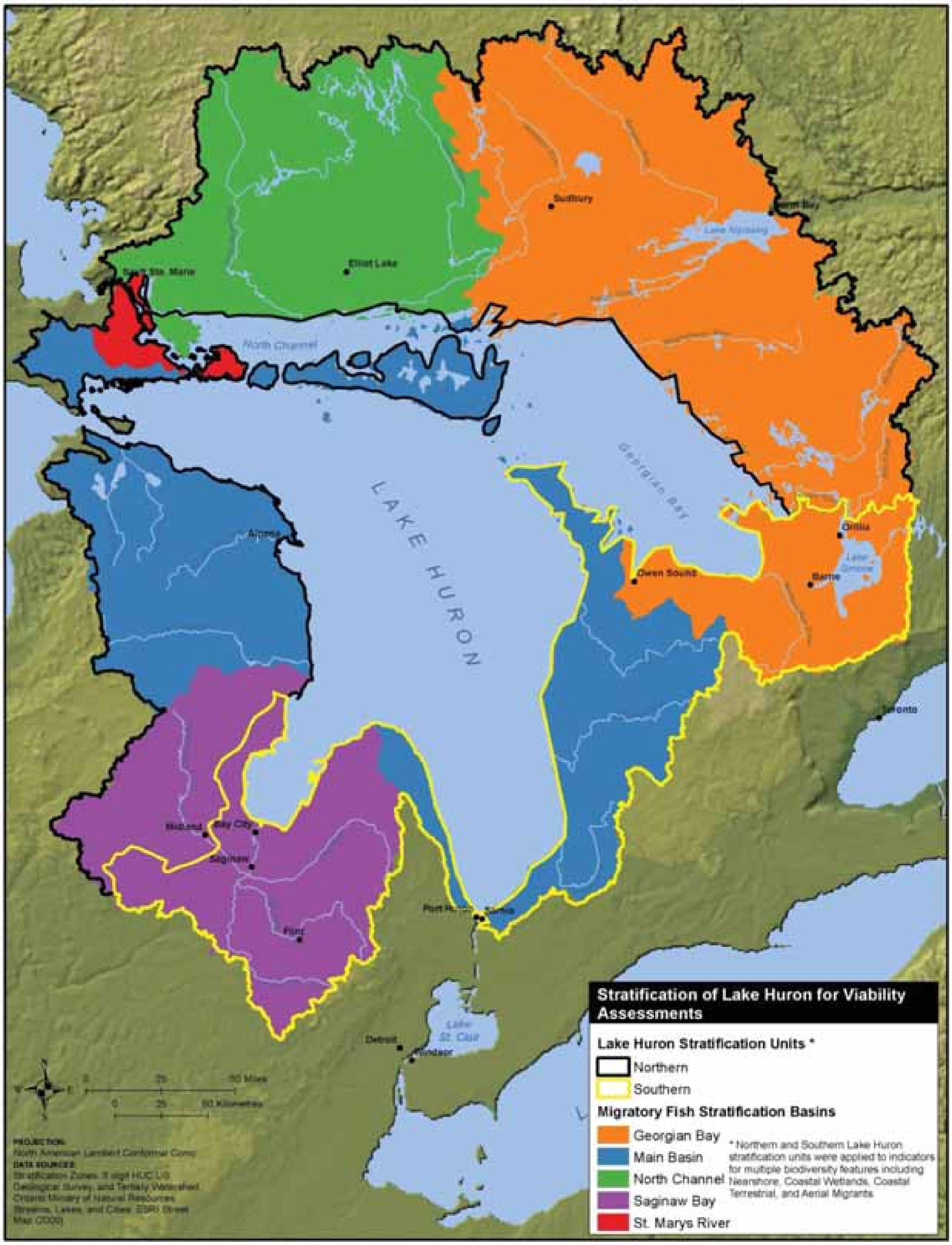

Figure 4: Stratification units for biodiversity feature viability assessments. Northern and Southern units were applied to indicators for multiple biodiversity features including Nearshore Zone, Coastal Wetlands, Coastal Terrestiral, and Aerial Migants; five basin units were used in the migatory fish assessment.

4.2 Summary of Current Viability of Lake Huron

The current viability rating for Lake Huron is FAIR, which by definition signifies that the lake is outside its acceptable range of variation and requires intervention, without which it is vulnerable to serious degradation (See above Methodology section for definitions of viability ratings). This rating confirms findings of complementary assessments including, the 2009 State of the Great Lakes report (Environment Canada and U.S. Environmental Protection Agency 2009) and validates the need for a strategy to address biodiversity conservation in Lake Huron.

> **Key Ecological Attributes (KEAs):** Aspects of a features biology or ecology that, if missing or altered, would lead to the loss of that feature over time.
>
> **Landscape context:** Assessment of the environmental and ecological processes that maintain the biodiversity feature.
>
> **Condition:** Measures of biological composition, structure, and biotic interactions.
>
> **Size:** Abundance or population size.

The overall viability rating is of limited value without consideration of the individual feature viability assessments upon which it is built. All biodiversity features except one (Islands) were assessed as having fair viability or health at present (Table 3). The different types of KEAs (Landscape Context, Condition, and Size) vary in their contribution to the viability rating for each feature. Landscape Context indicators are moderately degraded across all biodiversity features reflecting the dramatic conversion of watersheds and shoreline areas across the lake to non-natural land use types, especially in southern Lake Huron. For the Open Water Ecosystem and Native Migratory Fish features, significant reductions in the populations of many key fish and benthic organisms are reflected in the POOR ratings for Size and Condition, respectively. The condition of the Open Water Benthic and Pelagic feature is also degraded by invasive species and by recent and poorly understood changes in trophic structure. Also, though water clarity, oxygen concentration and contaminant loads in fishes (at least those that are known to affect egg incubation) in the Open Water Benthic and Pelagic feature retain GOOD or VERY GOOD ratings, the overall Landscape Context rating for this feature is FAIR due to POOR ratings for nutrients and detrital rain (see Open Water Benthic and Pelagic section in this chapter).

On the positive side, Lake Huron Islands remain in GOOD health and their continued conservation is highly feasible (Kraus et al. 2009). Similarly, some biodiversity features are faring better than others with respect to certain KEAs. The size of the Coastal Wetlands and Coastal Terrestrial System features remain in GOOD status, owing primarily to the comparatively intact nature of these ecosystems in northern Lake Huron but also to the persistence of these ecosystems (even in a degraded condition) in many parts of southern Lake Huron.

Table 3: Summary of current viability rating for all biodiversity features and Lake Huron as a whole.

	Biodiversity Features	Landscape Context	Condition	Size	Viability Rank
1	Open Water Benthic and Pelagic Ecosystem	FAIR	POOR	-	FAIR
2	Nearshore Zone	FAIR	FAIR	-	FAIR
3	Islands	-	GOOD	GOOD	GOOD
4	Native Migratory Fish	FAIR	-	POOR	FAIR
5	Coastal Wetlands	FAIR	FAIR	GOOD	FAIR
6	Coastal Terrestrial System	FAIR	FAIR	GOOD	FAIR
7	Aerial Migrants	FAIR	-	-	FAIR
	Lake Huron's overall biodiversity viability rank				FAIR

4.3 Detailed Viability Assessments for Biodiversity Features of Lake Huron

In this section, we describe biodiversity features, KEAs and associated indicators, and summarize the results of the viability assessments and desired ratings. The level of confidence of these assessments varies based on current knowledge (published research to expert opinion), so this assessment should be viewed as a work in progress and serve as a guide for future research and monitoring efforts. In addition, there are several indicators for which experts could not rate the current condition (Appendix C).

NOTES FOR THIS SECTION:

- In each of the ratings tables, the current status rating of an indicator is formatted in **bold**, and the desired future status rating is presented in *italics*.
- Some indicators (e.g., land cover metrics) are used for multiple biodiversity features, yet may be considered in different categories and may or may not use the same ratings thresholds because they hold different significance for different features. For example, **percent natural land cover within 2 km of shoreline** has different ratings for Nearshore Zone, Coastal Terrestrial System, and Coastal Wetlands and is in different categories. It is considered a *condition* indicator for Coastal Terrestrial System because it is *within* that feature, whereas it lies *outside* the Coastal Wetlands and Nearshore Zone features and is considered *landscape context*. Also, the ratings thresholds are based on its value as habitat for nested features (e.g., migrating land birds) in the Coastal Terrestrial System, but mostly as buffer for the other two features.
- Many of the indicators have qualitative ratings due to the lack of complete understanding of the relationship between the indicator and feature viability. They remain part of this assessment based on the consensus of the experts in each working group, and improving the ratings is recommended as a focus of ongoing and future study.

4.3a Open Water Benthic and Pelagic Ecosystem

Figure 5: The open water benthic and pelagic biodiversity feature.

The Open Water Benthic and Pelagic Ecosystem includes open waters beyond the 30 meter bathymetric contour from the mainland or islands, including reefs and shoals (Figure 5).

The indicators for the open water benthic and pelagic systems were evaluated for the entire lake. Experts recognize that there are differences among portions of the basin in terms of trends in many of the indicators, but currently available data do not support such stratification. Future assessments of viability should seek to stratify the evaluation of selected indicators.

Nested Biodiversity Conservation Features

- benthic macroinvertebrates (*Diporeia*)
- forage fishes (benthic and pelagic)
- piscivorous fish (benthic and pelagic)
- shoals/ reefs
- phytoplankton

Summary of Viability

The Open Water Benthic and Pelagic Ecosystem of Lake Huron has a viability status of FAIR, overall (Table 3). This rating is based on an assessment of twenty indicators, five related to landscape context and fifteen related to condition. Landscape context for this feature is entirely related to the KEA of water quality, and the five indicators vary in current status from VERY GOOD to POOR, with an overall rating of POOR (Table 4). Two indicators, *Detrital Rain* and *P:N:Si nutrient amounts*, are closely tied to the disruption of the food chain caused by non-native Dreissenid mussels. This disruption of the lower trophic levels has a cascading effect on the entire ecosystem and may be difficult to improve.

Condition indicators, overall, are rated as FAIR (Table 4). KEAs that inform the condition assessment include many related to species composition and structure including benthic species (macroinvertebrates) as well as predator and prey fish species. Though populations of some native fish species have been suppressed for decades by non-native species, several experts expressed optimism that many of these native populations have been increasing in recent years, following declines in alewife and Chinook salmon. This informed optimism lead to ratings of VERY GOOD for desired future status in several indicators and reflects the ongoing transition in the Lake Huron fish community (DesJardine et al. 1995).

Table 4: KEAs and indicators for the Open Water Benthic and Pelagic Ecosystem biodiversity feature.

KEAs and Indicators for Open Water Benthic and Pelagic Ecosystem						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context	Water quality	Contaminant load in fish tissue – appropriate for egg incubation	loads are a severe constraint on successful egg incubation	loads are a moderate constraint on successful egg incubation	loads may slightly inhibit successful egg incubation	***loads do not inhibit successful egg incubation***

KEAs and Indicators for Open Water Benthic and Pelagic Ecosystem						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context cont.	Water quality	Detrital rain	**TBD**	TBD	*TBD*	TBD
	Water quality	Oxygen concentration	TBD	TBD	**TBD**	*TBD*
	Water quality	P :N :Si nutrient amounts	**TBD**	TBD	*TBD*	TBD
	Water quality	Water clarity	TBD	TBD	**<12 or >15m**	*roughly 12 m*
Condition	Community architecture	Coregonids: Shortjaw Cisco -- found and verified in assessment gear	**Rarely found--some years undetected**	Presence in at least one sample per year	Present on an annual basis in a majority of appropriate habitat	*Always present in multiple size classes in appropriate habitat*
	Lake Trout/non-native salmonid balance	Alewife abundance	> 10 kg/ha	1-10 kg/ha	<1 kg/ha	***0.05 kg/ha or less***
	Lake Trout/non-native salmonid balance	Percentage of lake trout relative to salmon	< 25% Lake Trout	25-50% Lake Trout	50-75% Lake Trout	***> 75% Lake Trout***
	Native macroinvertebrates	Area of benthos inhabited by *Diporeia*– proportion of grab samples from lakewide survey with > 700/m² *Diporeia*	< 40% of sites	**40-60% of sites**	*60-80% of sites*	> 80% in lakewide survey
	Native macroinvertebrates	*Diporeia* -- Density of individuals in grab samples, >90 m depth	< 500/m²	**500 - 1000/m²**	*1000 - 2000/m²*	> 2000/m²

KEAs and Indicators for Open Water Benthic and Pelagic Ecosystem						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Condition cont.	Native macroinvertebrates	*Diporeia* -- Density of individuals in grab samples, 30-90 m depth	**< 500/m²**	500 – 1000/m²	*1000 – 4000/m²*	> 4000/m²
	Native macroinvertebrates	Non-native Dreissenids	Dreissenids present	**TBD**	TBD	Dreissenids absent
	Population size & dynamics	Coregonids: lake whitefish – number of year classes > yr 5	<4	4 - 6	7 - 10	***>10***
	Population size & dynamics	Lake trout: Spawning stock biomass/recruit	< 0.3 kg/recruit	0.3 - 0.5 kg/recruit	**> 0.5 - 0.75 kg/recruit**	*> 0.75 kg/recruit*
	Population size & dynamics	Proportion of wild Lake Trout in sample	**<5 spawning phase adults per 100m of net and/or <10% are wild**	5-10 spawning phase adults per 100m of net and 10-25% wild	>10-20 spawning phase adults per 100m of net and >25%-60% wild	*> 20 spawning phase adults per 100m of net of which >60% are wild*
	Population size of offshore prey fish species	Lake herring: total NUMBERS of Adult spawners/1000 ft survey net	**< 10**	10-50	*51-100*	> 100
	Predator fish species population size	Burbot: total numbers per 60 gill net lifts (1000ft nets)	< 10	***10-<30***	*30-40*	> 40
	Predator fish species population size	Lake trout: Spawning stock biomass -- # individuals over age-7 relative to total native fish population	< 1,000,000 kg in main basin	**1,000,000 – 2,000,000 kg in main basin**	> 2,000,000 – 5,000,000 kg in main basin	*> 5,000,000 kg in main basin*
	Predator fish species population size	Lake trout: YOY density (#/hectare)	<1/ha	**1 - 2/ha**	>2 - 10/ha	*>10/ha*

KEAs and Indicators for Open Water Benthic and Pelagic Ecosystem						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Condition cont.	Predator growth/Food availability	Lake trout: Growth based on asymptotic length	> 600 - 700	> 700 - 800	> 800 - 900	*> 900 mm*

**Note that most of the water quality indicators are considered important by the Open Water Ecosystem assessment team and should be retained for further development, but quantitative relationships to viability are unclear. Detrital rain is an exception in that both the U.S. EPA and EC collect data, but the assessment team was not able to compile data in time for this draft. TBD = to be determined.*

LANDSCAPE CONTEXT

KEA: Water quality

Indicator: Contaminant load in fish tissue – appropriate for egg incubation

Description: Levels of contaminants in fish tissue seem to have constrained egg incubation in other ecosystems, but not yet in the open waters of Lake Huron. The relationship of this indicator to viability has not yet been quantified, but the working group recommends monitoring in light of the emergence of new contaminants including fire retardants.

Basis for Assessing Indicator: These ratings are qualitative placeholders only and should be developed more fully in the future. More research is needed.

Current Status—VERY GOOD: Contaminant levels are currently very low in the open water ecosystem and are not affecting reproduction.

Desired Future Status—VERY GOOD: Maintaining current contaminant levels is a reasonable goal given better awareness and enhanced monitoring.

Indicator: Detrital rain

Description: Detrital rain is the settling of detritus through the water column and is characterized in terms of the amounts of phosphorous, nitrogen and other substances. This rain supplies nutrients that support the base of the food chain in the open water ecosystem. Data are collected by Environment Canada and the U.S. EPA, but is lacking at many sites.

Basis for Assessing Indicator: Ratings are not yet developed and will depend on a better understanding and more research of the relationship between the amount and quality of detrital rain and basic trophic processes.

Current Status—POOR: New studies indicate that spring diatom bloom is absent, indicating that detrital rain has been reduced to a level that is perturbing trophic relationships. The confidence of this rating could be improved through use of EPA surveys of diatom densities or biomass.

Desired Future Status—GOOD: This rating is based on expert opinion and could be improved by referencing available data that precede invasion by Dreissenids.

Indicator: Oxygen concentration

Description: The concentration of dissolved oxygen varies predictably in the open water ecosystem, and concentrations that fall outside of normal ranges can result in mortality of fish.

Basis for Assessing Indicator: These ratings are qualitative placeholders only and should be developed more fully in the future. More research is needed.

Current Status—GOOD: There are very few documented cases of problematic low oxygen levels in Lake Huron, but recent die-offs of open water species (whitefish) in Thunder Bay may indicate a developing problem. Increases in Dreissenids in deeper waters, combined with several days of no wind may have resulted in the Thunder Bay die-offs (Jim Johnson, pers comm.).

Desired Future Status—VERY GOOD: Based on expert opinion, this is a reasonable goal. There have been localized problems with low oxygen concentrations in the Nearshore Zone; this indicator requires continued monitoring.

Indicator: P :N :Si nutrient amounts

Description: The relative amounts of these nutrients should reflect adequate diatom production. Experts agree on the utility of this indicator, though numeric values for ratings are not yet developed. More research is needed.

Basis for Assessing Indicator: Reference measurements will be available in upcoming studies that will be published within the next two years (J. Schaeffer, pers. comm.)

Current Status—POOR: This rating is based on expert opinion and should be updated in the near future to reflect the results of ongoing studies.

Desired Future Status—GOOD: Experts agreed that achieving VERY GOOD status is not likely to be feasible without some unforeseen collapse of invasive Dreissenids.

Indicator: Water clarity

Description: Water clarity is a widely used index of water quality. Degraded water clarity is strongly related to multiple stressors including increased sediment loads, excess nutrients, and presence of pollutants.

Basis for Assessing Indicator: The ratings indicate an ideal value of roughly 12 to as high as 15. Values greater than 15 indicate a lack of plankton, an important component of the food chain. Values of fair and poor are not well substantiated at this point. More research is needed.

Current Status—GOOD: In general, water clarity has improved in recent years due in part to the effectiveness of Dreissenids in filtering out plankton and suspended sediments but also to improvements in stormwater management throughout the basin. It is not currently a constraint to viability, but clarity should be monitored and continued efforts to reduce sediments from contributing streams are warranted. A

confounding aspect of this indicator is that increasing clarity may reflect a severe decline in plankton, which would result in a reduction in viability for this feature.
Desired Future Status—VERY GOOD: This rating is based on expert opinion.

CONDITION

KEA: Community architecture

Indicator: Coregonids: shortjaw cisco -- found and verified in assessment gear
Description: The presence of cisco on a regular basis would be an indicator of recovery of this species. This species is considered to be of "Special Concern" by the USFWS, indicating that it should be monitored for potential future listing.

Basis for Assessing Indicator: Based on expert opinion, the indicator ratings reflect capture rates that would indicate varying stages of species recovery.

Current Status—POOR: Shortjaw cisco have been found in U.S. Geological Survey (USGS) surveys only once in the last ten years.
Desired Future Status—GOOD: The recent collapse of alewives in Lake Huron lends hope that this prey species may recover.

KEA: Lake Trout/non-native salmonid balance

Indicator: Alewife abundance
Description: The abundance of alewives, as the primary prey of Chinook salmon, has a direct effect on the balance between lake trout (*Salvelinus namaycush*) and non-native salmonids. Alewife abundance is easily documented in seasonal surveys undertaken by agencies, especially USGS. Low densities of alewife are seemingly better for natural reproduction of native species. Saginaw bay walleye and perch reproduction has exploded with the recent decline of alewife; and Lake Trout Thiamine deficiency (related to high thiaminase levels caused by eating too many alewives) is no longer limiting lake trout reproduction.

Basis for Assessing Indicator: These ratings are based on years of data on alewife abundance and management of the non-native salmonid fishery.

Current Status—VERY GOOD: Only four alewives were detected in the 2009 lakewide acoustic assessment (Jeff Schaeffer pers. comm.). This result provides a strong basis for the current status.
Desired Future Status—VERY GOOD: Though the persistence of the alewife decline is yet to be seen, experts were comfortable that this indicator would be maintained.

Indicator: Percentage of lake trout relative to salmon
Description: The percentage of lake trout relative to salmon, when combined with abundance data, provide a sound index of the condition of the upper trophic level of the open water ecosystem.

Basis for Assessing Indicator: The ratings are based on MDNR fisheries creel data, which are collected annually over a long period of time and have been used as a key piece of information in fisheries management.

Current Status—VERY GOOD: On the U.S. side, 2009 creel data indicated 98% lake trout.
Desired Future Status—VERY GOOD: There is room for a decrease in the current status and still maintain desired status overall.

KEA: Lake Native macroinvertebrates

Indicator: Area of benthos inhabited by *Diporeia* – proportion of grab samples from lakewide survey that have greater than 700/m² *Diporeia*
Description: This indicator describes the distribution and abundance of a key macroinvertebrate to the offshore foodweb, and one that has declined markedly in recent years.

Basis for Assessing Indicator: The ratings are based on research in Lake Huron and reflect the role of *Diporeia* in trophic dynamics.

Current Status—FAIR: Current data collected by USGS and National Oceanographic and Atmospheric Administration (NOAA) are the basis for this rating.
Desired Future Status—GOOD: Dreissenids ultimately constrain populations of *Diporeia*, and they show no signs of decreasing in the foreseeable future, so a rating of VERY GOOD is highly unlikely.

Indicator: *Diporeia*—density of individuals in grab samples, >90 m depth
Description: As with the above indicator, this one is meant to track the abundance of a key component of the food chain in deeper open waters.

Basis for Assessing Indicator: The ratings are based on long-term data and reflect ranges that are important to trophic interactions.

Current Status—FAIR: The current status reflects a long-term decline in *Diporeia* associated with expansion of Dreissenids into deeper water.
Desired Future Status—GOOD: Dreissenids ultimately constrain populations of *Diporeia*, and they show no signs of decreasing in the foreseeable future, so a rating of VERY GOOD is highly unlikely.

Indicator: *Diporeia*—density of individuals in grab samples, 30-90 m depth
Description: This is the third indicator of *Diporeia* and tracks abundance at intermediate depths.

Basis for Assessing Indicator: Data have been collected since the early 1970s by NOAA GLERL and USGS. These ratings reflect well documented relationships between *Diporeia* and their predators (Nalepa et al. 2007).

Current Status—POOR: At these moderate depths, *Diporeia* populations have experienced severe declines.

Desired Future Status—GOOD: Due to the likely persistence of Dreissenids, the most feasible improved status of this indicator is GOOD.

Indicator: Non-native Dreissenids

Description: This may be the most direct and effective indicator for tracking the invasion of these mussels (Tom Nalepa pers. comm.). However, sampling can be expensive.

Basis for Assessing Indicator: Data to establish ratings are currently lacking, but the ratings for POOR and VERY GOOD should be based on presence absence. Dreissenid presence at a site seems to result in loss of *Diporeia* even if Dreissenid densities are low. The relative density seems to be less important than presence/absence (French et al. 2009).

Current Status—POOR: This rating is a best guess, based on observations of Dreissenids over many years in multiple locations. Measurements are necessary to test this guess.
Desired Future Status— VERY GOOD: Establishing this rating will require more sampling and assessment of recent trends.

KEA: Population size & dynamics

Indicator: Coregonids: lake whitefish – number of year classes > yr 5

Description: The number of mature year classes greater than yr 5 is an indicator of population demographics and ongoing recruitment success. Data are collected by OMNR and USGS.

Basis for Assessing Indicator: Ratings are based on reference data from pre-invasion of Dreissenid and are well accepted by experts.

Current Status—VERY GOOD: Adult age classes are still diverse, but younger classes are declining and this indicator is likely to degrade in the near future.
Desired Future Status—VERY GOOD: The current trend among younger age classes is likely to be reversed in the foreseeable future. So it is expected that maintaining this rating is feasible.

Indicator: Lake trout: spawning stock biomass/recruit

Description: This indicator is modeled by the Great Lakes Fisheries Commission Lake Huron Technical Committee and is an indicator of survival. Data to support the model are gathered by MDNR and OMNR.

Basis for Assessing Indicator: The ratings are based on ongoing research and modeling as described above.

Current Status—GOOD: Data indicate variability around the lake, with better sampling units showing values that exceed 0.5 kg/recruit among both wild and stocked fish (Johnson et al. 2004).
Desired Future Status—VERY GOOD: The current trajectory is flat, but with the decline in alewives and predicted increase in native prey fish, this indicator is likely to improve.

Indicator: Proportion of wild lake trout in sample

Description: This indicator reflects the population size of naturally reproducing lake trout in Lake Huron. Data are collected by multiple agencies and compiled by the Lake Huron Technical Committee of GLFC.

Basis for Assessing Indicator: The ratings are calibrated to sampling effort and are based on long-term data collection.

Current Status—POOR: This indicator varies widely among basins but probably averages in the poor category. There is a slightly increasing trend in the data that is likely to continue.

Desired Future Status—GOOD: The current trend in the data and management goals directed at more wild fish bode well for this indicator; it should improve markedly in the foreseeable future. We are seeing more wild fish in most of the surveys. Their appearance is so recent that there have been few publications. Young wild fish started to appear a few years after wild reproduction was first observed in 2004. Those fish are just now being recruited to gill net fisheries (Jeff Schaeffer pers. comm.).

KEA: Population size of offshore prey fish species

Indicator: Lake herring: total NUMBERS of Adult spawners/1000 ft survey net

Description: Data on lake herring biomass and numbers are being collected and historic data can be found in GLFC Lake Huron Technical Committee reports.

Basis for Assessing Indicator: Ratings have been developed based on long-term data but are still rough; further surveys and analyses are needed to refine indicator ratings.

Current Status—POOR: Data indicate that lake herring numbers are still depressed from reference conditions; and they are still listed as state threatened in Michigan.

Desired Future Status—GOOD: Though recent numbers do not indicate an upward trend, the MDNRE has a restoration plan for lake herring in Lake Huron. The current depressed status of alewife offers a window of opportunity, and current efforts to raise and stock lake herring are underway.

KEA: Predator fish species population size

Indicator: Burbot: total numbers per 60 gill net lifts (1000ft nets)

Description: Burbot are an important predator species that have been tracked by MDNR Fisheries Division.

Basis for Assessing Indicator: These ratings are based on best understanding of trends in the data, but could be refined by combining with the modeling process used by GLFC Lake Huron Technical Committee.

Current Status—FAIR: This rating is based on MDNR data and will likely be refined along with the GLFC modeling process.

Desired Future Status—GOOD: This desired rating is a rough estimate of what might be feasible in the foreseeable future.

Indicator: Lake trout: spawning stock biomass (# individuals greater than age-7 relative to total native fish population)
Description: This indicator reflects the capacity for spawning within the lake trout population.

Basis for Assessing Indicator: The cutoff between Poor and Fair is given in the ratings, but is currently an educated guess. The model used to develop this rating (Lake Trout Stock Assessment Model of MDNR) is based on data from the main basin only and may not apply to other basins. A GOOD rating for this indicator might be 2 million to 5 million kg.
Further assessment is needed.

Current Status—FAIR: Values for the main basin exceed 1,000,000 kg and are decreasing slightly (Jim Johnson, pers. comm.). In 2009, there were 145 million kg of pelagic prey in Huron. Based on the latest surveys and an estimated trophic efficiency of 10%, a rough estimate of predatory fish biomass (including burbot, smallmouth bass, walleye, and pacific salmon) in the main basin is 14.5 million kg. The current status of lake trout biomass is estimated at between 1,000,000 and 2,000,000 kg based on these data.
Desired Future Status—VERY GOOD: Future values are likely to reach a VERY GOOD status given trends in the abundances of alewife and pacific salmon and the increase in young lake trout. Management priorities in both Canada and the U.S. are also favorable to improvement of this indicator.

Indicator: Lake trout: young of the year density (#individuals/hectare)
Description: Lake trout young of the year is a good indicator for two reasons: (1) establishing self-sustaining lake trout is a common goal for management agencies; and (2) lake trout reproduction is generally considered a good sign of ecosystem health (food quality, spawning habitat, and well-managed fishing pressure). This measure is based on wild fish only.

Basis for Assessing Indicator: Ratings are based on data collected by MDNR and USGS. Data are also being tracked in Lake Superior and could serve as a reference.

Current Status—FAIR: Young of the year were first caught within the last decade and numbers peaked in 2004 at around 1 per hectare. The current trend is flat.
Desired Future Status—VERY GOOD: Lake trout are recovering and achieving full viability is a feasible outcome of management strategies and the decline in alewives.

KEA: Predator growth/Food availability

Indicator: Lake trout: growth based on asymptotic length
Description: This indicator assesses trends in length and is closely tied to food availability. MDNR has been collecting data to support this indicator for all sizes of trout.

Basis for Assessing Indicator: The indicator ratings are based on modeling through the GLFC Lake Huron Technical Committee and are currently a rough guess.

Current Status—POOR: Larger fish are not reaching maximum size, indicating that the food chain has not recovered from alewife expansion and collapse.

Desired Future Status—GOOD: Though conclusive evidence is yet lacking, current trends in survival and growth of lake trout, as well as other related indicators, is a source of optimism among some experts. This indicator is likely to improve, but the degree of improvement is hard to predict.

4.3b Nearshore Zone

Figure 6: Map of the Nearshore Zone biodiversity feature.

The Nearshore Zone biodiversity feature includes the submerged lands and waters of Lake Huron ranging from 0 to 30 meters in depth (Figure 6). Because Lake Huron water levels are dynamic—varying seasonally and annually—so too is the Nearshore Zone dynamic, with Coastal Terrestrial System and Open Water Ecosystem areas becoming Nearshore Zone in some years, and vice versa. The Nearshore Zone includes a variety of substrate types, as well as submerged and emergent aquatic vegetation. Coastal Wetlands are a critical habitat within the Nearshore Zone, but are detailed as a separate feature because of their importance to Lake Huron biodiversity. To the extent that Coastal Wetlands influence nearshore species assemblage structure or processes outside of marsh habitats, they were also considered in this assessment. The Nearshore Zone is the most productive portion of Lake Huron and supports a higher richness and diversity of fish and invertebrates than Open Water Ecosystem habitats. The structure and function of the Nearshore Zone influence several other biodiversity features, including the Open Water Ecosystem, Coastal Wetlands, Native Migratory Fish, and Coastal Terrestrial System.

Some of the indicators for the Nearshore Zone feature that apply to Coastal Wetlands and inland KEAs were stratified by Northern and Southern Lake Huron (see section 4.1 Methodology). Most of the indicators, however, were not stratified.

Nested Biodiversity Conservation Features

- benthic macroinvertebrates, such as burrowing mayflies (*Hexagenia*)
- fish: walleye (*Sander vitreus),* yellow perch (*Perca flavescens*), smallmouth bass (*Micropterus dolomieu*), lake herring (*Coregonus artedi*), lake sturgeon (*Acipenser fulvescens*)
- spawning habitat for offshore fishes like lake herring (*Coregonus artedi*), lake whitefish (*Coregonus clupeaformis*), lake sturgeon (*Acipenser fulvescens*)
- reptiles: snapping turtle (*Chelydra serpentine*), map turtle (*Graptemys geographica*), musk turtle (*Sternotherus ordoratus*) and spiny softshell turtle (*Apalone spinifera*)
- waterfowl, shorebirds
- native submerged aquatic vegetation

Summary of Viability

The Nearshore Zone biodiversity feature of Lake Huron has a viability status of FAIR, overall, with FAIR ratings in both the landscape context and condition categories (Table 3). This rating is based on an assessment of twenty two indicators, twelve related to landscape context and ten related to condition. Landscape context for this feature incorporates KEAs of water chemistry, land use in adjacent coastal areas and contributing watersheds, and sediment stability and movement. These indicators were mostly evaluated as having current status of FAIR or GOOD, with only two in VERY GOOD status (artificial shoreline hardening in northern and southern Lake Huron) and none rated as POOR (Table 5).

Condition KEAs include *community architecture*, *food web linkages*, and *spawning habitat quality and accessibility*. Current status ratings for indicators in this category are all either FAIR or POOR. Indicators rated as poor describe average population yields of native fish such as lake sturgeon, walleye, and yellow perch, density of *Hexagenia* populations, and access to spawning habitat for reef-spawning fishes. Those that are rated FAIR include the abundance of exotics, densities of rotifers and other invertebrates, native fish species richness, smallmouth bass relative abundance, and access to spawning habitat for fish that spawn in Coastal Wetlands or sand, gravel, or cobble substrates.

Table 5: KEAs and indicators for the Nearshore Zone biodiversity feature.

KEAs and Indicators for Nearshore Zone						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context	Coastal and watershed contribution	Artificial Shoreline Hardening Index--northern Lake Huron	>40%	30-40%	20-30%	***<20%***
	Coastal and watershed contribution	Artificial Shoreline Hardening Index--southern Lake Huron	>40%	30-40%	20-30%	***<20%***
	Coastal and watershed contribution	Percent natural land cover in watershed--northern Lake Huron	<20%	20-45%	**>45-80%**	*>80%*
	Coastal and watershed contribution	Percent natural land cover in watershed--southern Lake Huron	<20%	20-45%	***>45-80%***	>80%
	Coastal and watershed contribution	Percent natural land cover within 2 km of lake--northern Lake Huron	<20%	20-45%	***45-80%***	>80%
	Coastal and watershed contribution	Percent natural land cover within 2 km of lake--southern Lake Huron	<20%	20-45%	***45-80%***	>80%
	Landscape pattern (mosaic) & structure	Native vegetation cover/SAV distribution in protected embayment's and soft sediment areas	Absence or near absence of vegetation cover/critical habitat for small fish and YOY	**Moderate level of vegetation cover (emergent and submergent)**	*Sufficient levels of vegetative cover for critical faunal species habitat*	Diverse plant assemblages, SAV dominant

KEAs and Indicators for Nearshore Zone						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context cont.	Soil / sediment stability & movement (land context)	Bed load traps and groins (number of structures per length of shoreline)--northern Lake Huron	>300 structures/ 100 km shoreline	>200-300 structures/ 100 km shoreline	***30-200 structures/ 100 km shoreline***	<30 structures/ 100-km shoreline
	Soil / sediment stability & movement (land context)	Bed load traps and groins (number of structures per length of shoreline)--southern Lake Huron	>300 structures/ 100 km shoreline	>200-300 structures/ 100 km shoreline	***30-200 structures/ 100 km shoreline***	<30 structures/ 100-km shoreline
	Soil / sediment stability & movement (land context)	Erosion and deposition rates--northern Lake Huron	High soil erosion by water risk (>22 t/ha/yr)	Moderate soil erosion by water risk (11-22 t/ha/yr)	**Low soil erosion by water risk (6-11 t/ha/yr)**	*Very low soil erosion by water risk (<6 t/ha/yr)*
	Soil / sediment stability & movement (land context)	Erosion and deposition rates--southern Lake Huron	High soil erosion by water risk (>22 t/ha/yr)	**Moderate soil erosion by water risk (11-22 t/ha/yr)**	*Low soil erosion by water risk (6-11 t/ha/yr)*	Very low soil erosion by water risk (<6 t/ha/yr)
	Water chemistry	Phosphorous concentrations & dynamics	>30 µg/L for any nearshore location or an average across the nearshore lakewide of >7.5 µg/L	**15 - 30 µg/L at any nearshore location, and an average across the nearshore lakewide of 5.0-7.5 µg/L**	*<15 µg/L for each nearshore location, and an average across the nearshore lakewide of 5.0-7.5 µg/L*	<15 µg/L for each nearshore location, and an average across the nearshore lakewide of <5.0 µg/L
Condition	Community architecture	Abundance and distribution of exotics	Increasing rate of exotics introduction, establishment	**Reduced rate of new introductions; increasing levels of abundance and distribution of existing exotics**	Reduced rate of new introductions; no net gain in existing exotic distribution	*Preventing establishment of new exotics; reduced abundance & distribution of existing exotics*
	Community architecture	Lake sturgeon population five-year average yield	**Small populations with large portions of**	Mostly small populations, but some stronger	Several strong populations in both US and Canada; all	*At least one strong, viable spawning population*

KEAs and Indicators for Nearshore Zone						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Condition cont.			**Lake Huron without spawning populations**	populations and all major portions of the lake with at least small spawning population	major sections of the lake with a spawning population; removal from threatened status in US waters	*within each major section (e.g., Saginaw Bay, North Channel) of Lake Huron*
	Community architecture	Native fish species richness	Lack of native species diversity	**Moderate diversity of native species**	*Dominated by a variety of native species*	Diverse array of fish to support healthy, productive fish communities
	Community architecture	Smallmouth bass population relative abundance	Less than ½ of representative populations meeting goals for relative abundance/CPUE	**At least ½ of representative populations meeting goals for relative abundance/CPUE**	At least ¾ of representative populations meeting goals for relative abundance/CPUE & remaining populations at >80% of goal	*Each representative population meeting goals for relative abundance/CPUE*
	Community architecture	Walleye population five-year average annual	**Yield <350,000 kg**	Yield 350,000 - 700,000 kg	*Yield 700,000 - 1,000,000 kg*	Yield >1,000,000
	Community architecture	Yellow perch population five-year average annual	**Yield <250,000 kg**	Yield 250,000 - 500,000 kg	*Yield 500,000 - 750,000 kg*	Yield >750,000
	Food web linkages	Hexagenia mean density in softshore mesotrophic waters	**<9 nymphs per m-2**	9-63 nymphs per m-2	63-136 nymphs per m-2	*>136 nymphs per m-2*
	Food web linkages	Mean densities of rotifers, copepods, and cladocerans in early summer	Rotifers <100 ind/L Copepods <50 ind/L Cladocerans	**Rotifers 100-150 ind/L** **Copepods 50-75 ind/L** **Cladocerans**	*Rotifers 150-300 ind/L* *Copepods 75-125 ind/L* *Cladocerans*	Rotifers >300 ind/L Copepods >125 ind/L Cladocerans

KEAs and Indicators for Nearshore Zone

Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
			<35 ind/L	**35-50 ind/L**	*50-75 ind/L*	>75 ind/L
Condition cont.	Spawning habitat quality and accessibility	Spawning/recruitment success of representative coastal wetland spawners (key indicators are yellow perch, northern pike, muskellunge)	Very little recruitment, so that populations are severely declining or being maintained at levels much lower than historic range	**Some recruitment, but populations are in decline or are being maintained at levels well below the historic range**	*Good recruitment so that populations are increasing or being maintained at levels near the historic range-of variability*	Recruitment is maintaining populations well w/in historic range-of-variability or is increasing abundance toward historic range
	Spawning habitat quality and accessibility	Spawning/recruitment success of representative nearshore gravel/sand/cobble spawners (key indicators are smallmouth bass and emerald shiner)	Very little recruitment, so that populations are severely declining or being maintained at levels much lower than historic range	**Some recruitment, but populations are in decline or are being maintained at levels well below the historic range**	*Good recruitment so that populations are increasing or being maintained at levels near the historic range-of variability*	Recruitment is maintaining populations well w/in historic range-of-variability or is increasing abundance toward historic range
	Spawning habitat quality and accessibility	Spawning/recruitment success of representative nearshore reef spawning species (key indicators are lake trout, lake herring, lake whitefish)	**Very little recruitment, so that populations are severely declining or being maintained at levels much lower than historic range**	Some recruitment, but populations are in decline or are being maintained at levels well below the historic range	*Good recruitment so that populations are increasing or being maintained at levels near the historic range-of variability*	Recruitment is maintaining populations well w/in historic range-of-variability or is increasing abundance toward historic range

LANDSCAPE CONTEXT

KEA: Coastal and watershed contribution

<u>Indicator: Artificial Shoreline Hardening Index</u>
Description: Percent of shoreline protected with artificial structures (e.g., sea walls, rip rap) to prevent erosion. Shoreline hardening disrupts natural nearshore coastal processes that drive erosion and sediment transport, and therefore the nature and extent of Nearshore Zone habitats and community structure of Great Lakes shorelines (Meadows et al. 2005). Experts state that the impacts of shoreline hardening have been underestimated in the Great Lakes, relative to other threats like degraded water quality (Scudder Mackey, pers. comm.). This indicator is also used in the Coastal Terrestrial System assessment.

Basis for Assessing Indicator: Data to inform thresholds for shoreline hardening in the Great Lakes are difficult to obtain. We adopted the same indicator rankings utilized in the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009), which were loosely based upon a shoreline hardening State of the Lake Ecosystem Conference (SOLEC) indicator (EC and EPA 2007, p. 315-317). This will provide consistency and comparability between plans, given that no additional data have been identified to suggest alternative indicator rankings.

Northern
Current Status—VERY GOOD: The rating is based on NOAA's Great Lakes Environmental Research Laboratory data (GLERL 1997) as presented in SOLEC 2009 (EC and EPA 2009), which describes 3.1% of Lake Huron coastal units as >70% hardened, 1.1% as 40-70% hardened, 4.5% as 15-40% hardened, and 91% as <15% hardened (total of 10.6% hardened). However, experts in the Nearshore Zone working group estimated that Lake Huron's shoreline is 30-40% hardened, suggesting that major areas of the lake have been hardened and therefore the average hardened area is probably a little over 30%. This discrepancy and the experts sense the degradation caused by altered shorelines merits something other than a VERY GOOD rating suggest two things: 1) that further analyses are needed to better rank this indicator; and 2) that the rating thresholds should be adjusted to set a higher bar for a VERY GOOD, perhaps a 10% threshold instead of the current 20% threshold used in Lake Ontario and this report.
Desired Future Status—VERY GOOD: This rating is based on the importance of shoreline processes and the likelihood of maintaining or restoring shoreline in many areas.

Southern
Current Status—VERY GOOD: See description above for northern Lake Huron.
Desired Future Status—VERY GOOD: This rating is based on the importance of shoreline processes and the likelihood of maintaining or restoring shoreline in many areas.

<u>Indicator: Percent natural land cover within 2 km of shoreline</u>
Description: The amount of natural land cover[2] within 2 km of Lake Huron assessed for the northern and southern portion of the lake. The percent of development within the Coastal Terrestrial System of the Great

[2] Natural land cover includes all native vegetation and excludes agricultural, industrial, commercial, transportation and developed cover classes, and also excludes water. Plantations of trees were not distinguished from natural forests for this assessment.

Lakes has similar impacts on the Nearshore Zone as watershed land use (Uzarski et al. 2005). The literature indicates that alteration of natural land cover within Coastal Terrestrial Systems (ex. coastal forests or grasslands) may have a significant impact on the Nearshore Zone and coastal aquatic habitat and its inhabitants and on water quality and quantity within the watershed (SOLEC 2008, Dodd and Smith 2003). This indicator is also used for the Nearshore Zone and Coastal Terrestrial Systems assessment; the 2 km distance was selected based on studies of migrating landbirds (Ewert and Hamas 1995) and to be consistent with the Lake Ontario Biodiversity Conservation Strategy.

Basis for Assessing Indicator: As with watershed land use, most published studies are generally insufficient for identifying thresholds in impacts. As a result, we utilized the same thresholds used for watershed impacts derived from data in Lougheed et al. (2001) and Niemi et al. (2009). Ideally these ratings would be based on more data and evaluation of relationships between percent development and biotic community metrics (e.g., IBIs, ordination axes); future research on this relationship is needed.

Northern
Current Status—GOOD: The rating is based on GIS analyses of watershed land cover that produced a measurement of 61.5%. Interestingly, unlike watershed development, coastal development does not strongly follow a north-south gradient. As a result, watershed and coastal development patterns can be uncorrelated (Uzarski et al. 2005).
Desired Future Status—GOOD: This rating is an educated guess based upon the low likelihood of reaching VERY GOOD status.

Southern
Current Status—GOOD: The rating is based on GIS analyses of watershed land cover that produced a measurement of 53.7%.
Desired Future Status—GOOD: This rating is an educated guess based upon low likelihood of reaching VERY GOOD status.

<u>**Indicator: Percent natural land cover in contributing watershed**</u>
Description: The amount of natural land cover within the watershed contributing to a Nearshore Zone reach. There are substantial data indicating that the percent of development within the contributing watershed of Great Lakes Nearshore Zone is important in determining water quality and biological integrity (Lougheed et al. 2001, Uzarski et al. 2005, Niemi et al. 2009). A similar indicator is used for the Coastal Wetlands assessment, but it is focused on the watersheds for northern and southern Lake Huron.

Basis for Assessing Indicator status: Most published studies are generally insufficient for identifying thresholds for impacts. Indicator ratings for this metric are based on data presented in Lougheed et al. (2001), which are supported by data presented in Niemi et al. (2009). These ratings are generally consistent with expert opinion.

Northern
Current Status—GOOD: The rating is based on GIS analyses of watershed land cover, which produced a measurement of roughly 65%.
Desired Future Status—VERY GOOD: This rating is based on the desire to maintain high quality conditions across northern Lake Huron and its contributing waters.

Southern

Current Status—GOOD: The rating is based on GIS analyses of watershed land cover which produced a measurement of roughly 50%.

Desired Future Status—GOOD: Focus should be on limiting unplanned urban growth and second home development and establishing natural land cover in strategic areas, such as riparian greenways.

KEA: Landscape pattern (mosaic) & structure

Indicator: Native vegetation cover/submerged aquatic vegetation (SAV) distribution in protected embayments and soft sediment areas

Description: Naturally vegetated (submerged aquatic vegetation, SAV) Nearshore Zones outside of Coastal Wetlands. The value of this indicator was debated by experts, some of whom feel that SAV doesn't occur outside of Coastal Wetlands and others who hold that it does and is a useful indicator. Little is know about the current or historic distribution or extent of SAV in Lake Huron Nearshore Zone habitats outside of Coastal Wetlands. There are historic accounts of large Nearshore Zone expanses that had abundant SAV in areas such as Saginaw Bay, but historic data on submerged aquatic vegetation are scarce and spatially limited (Freeman 1974). Given the importance of SAV as structure for aquatic organisms and for productivity in general (Randall et al. 1996), these areas are likely very important in influencing Nearshore Zone communities. The importance of this indicator varies substantially across the lake, depending on substrate, exposure to wind, and wave energy.

Basis for Assessing Indicator: Qualitative placeholders are used for thresholds; analysis is needed to identify quantitative thresholds.

Current Status—FAIR: This rating applies to the entire lake, though the occurrence of SAV would be highly variable across the lake since conditions in many Nearshore Zones are not appropriate. Where this rating is applicable, many localized areas are believed to be FAIR or potentially POOR. This rating is based on expert opinion. More comprehensive spatial information on historic SAV outside of coastal marshes would need to be developed through research or modeling to quantitatively assess the current status of this indicator. Perhaps the increase in SAV following the zebra mussel invasion (Skubinna et al. 1995) could be utilized to help reconstruct historic vegetation coverage using a pre- and post-zebra mussel comparison. The rating of this indicator is likely different between Georgian Bay and the main lake.

Desired Future Status—GOOD: This rating seems feasible and is an educated guess.

KEA: Soil / sediment stability & movement

Indicator: Bed load traps and groins

Description: Artificial structures, such as docks, jetties, and breakwaters that project out into the lake and disrupt littoral flow patterns and sediment processes. It also includes other alterations such as dredging for water access and infilling that disrupt sediment processes include trapping of sediment on the updrift side of structures resulting in sediment-starved conditions on the downdrift side (Meadows et al. 2005). There are substantial data indicating that bed load traps and groins alter shoreline processes, particularly water flow and sediment transport (Herdendorf 1973, 1987, Carter et al. 1981, Li et al. 2001, Meadows et al. 2005). It is important to note that Nearshore Zone experts recommended that this metric incorporate both the number of structures and the size of structures, in recognition of the fact that structures that extend out further into the lake (500-1000') are especially disruptive with greater impacts that extend much further down the shoreline. Shoreline structure densities in Goforth and Carman (2005) did not discriminate between large and small structures, so further evaluation of this indicator ratings is needed in the future. This indicator is also used in the Coastal Terrestrial Systems assessment.

Basis for Assessing Indicator: Published studies are generally insufficient for identifying thresholds of impacts; however, in Goforth and Carman (2005) fish assemblages appear to be severely degraded by 300 trap and groin structures per 100 km of updrift shoreline. Therefore, this break was used to delineate between FAIR and POOR. Other breaks were set incrementally and adopted from the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group. 2009), which were based on thresholds developed from the following articles Swedish Environmental Protection Agency 2006 (Environmental Quality Criteria for Coasts; Dave 2001).

Northern

Current Status—GOOD: In general, experts said that most of northern Lake Huron had low densities of bed load traps and groins. This rating is based on expert opinion, but should be validated with analysis in the future.

Desired Future Status—GOOD: Maintaining an overall goal of GOOD is dependent upon maintaining significant areas of the lake that are VERY GOOD. Restoration of areas would also help to maintain a GOOD rating.

Southern

Current Status—FAIR: In general, experts said that many areas in southern Lake Huron and southern Georgian Bay have relatively high densities of shoreline alterations—mostly near urbanized areas, with some southern Lake Huron shoreline reaches with densities associated with a GOOD rating, but others with POOR. Rating is based on expert opinion, but should be validated with analysis in the future.

Desired Future Status—GOOD: This rating is an educated guess based upon a low likelihood of reaching VERY GOOD status. Reaching an overall goal of GOOD is dependent upon maintaining current GOOD and VERY GOOD areas and restoring other areas.

<u>Indicator: Erosion and deposition rates</u>

Description: Contributions of sediment loading from tributary rivers and steams, particularly related to elevated sediment loading (and not capturing sediment starved conditions as with mainstem dams).

Basis for Assessing Indicator: This indicator was adopted from the viability analysis for the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009). It was based upon several studies evaluating watershed impacts to the Nearshore Zone ecosystem (Ouyang et al. 2005, Baird and Associates 2005).

Northern:

Current Status—GOOD: The northern portions of the lake maintain many areas that are in VERY GOOD condition, but there are also areas within the basin in GOOD or FAIR condition to justify an overall GOOD rating. This rating is based on expert opinion, but should be validated with analysis in the future.

Desired Future Status—VERY GOOD: This rating is an educated guess based upon the likelihood of reaching this goal. Reaching goal is dependent upon maintaining areas rated as VERY GOOD, maintenance of most of the rest of the northern portions of the lake as GOOD and some rehabilitation to improve FAIR areas and some GOOD areas.

Southern:
Current Status—FAIR: The southern portions of the lake maintain some areas that are GOOD, but also maintains many areas that are FAIR and POOR. This rating is based on expert opinion, but should be validated with analysis in the future.
Desired Future Status—GOOD: This rating is an educated guess based upon a low likelihood of reaching VERY GOOD status. Reaching an overall goal of GOOD is dependent upon maintaining significant areas as GOOD, rehabilitation of many FAIR or POOR areas, and potentially even rehabilitating some GOOD areas to VERY GOOD.

KEA: Water chemistry

Indicator: Phosphorus concentrations & dynamics
Description: Phosphorus concentrations across the Lake Huron Nearshore Zone.

Basis for Assessing Indicator: The goal for Saginaw Bay overall, which maintains the highest phosphorus concentrations within Lake Huron, is set at 15.0 µg/L (GLWQA 1987), Dobiesz et al. 2005, Lake Huron Binational Partnership 2006). This concentration therefore represents a maximum threshold between FAIR and GOOD. The only Nearshore Zone location that generally does not attain this goal is Saginaw Bay (Dobiesz et al. 2005). While this represents a standard that all Nearshore Zones should maintain, many portions of the lake would be considered degraded if they approached this concentration. As a result, this indicator represents not only this minimum standard (15.0 µg/L), but also a lakewide Nearshore Zone mean that should be maintained. The Open Water Ecosystem phosphorus goal (SOLEC) for Lake Huron is <5.0 µg/L (EC and EPA 2005). Since this is an Open Water Ecosystem goal, this would represent a very low value for the Nearshore Zone, this concentration was set as a VERY GOOD value for the lakewide Nearshore Zone mean. GOOD was therefore identified as both <15.0 µg/L for all Nearshore Zone and between 5.0-7.5 µg/L averaged across all Nearshore Zones.

Current Status—FAIR: This rating applies to the entire lake, with some areas (e.g., Saginaw Bay) contributing disproportionately with values >15 µg/L. In general, southern Lake Huron has higher phosphorus concentrations adjacent to agricultural and urban watersheds. Increases in phosphorus in low nutrient areas such as Georgian Bay further reduce average phosphorus concentrations across the lake. Rating is based on data from Johengen et al. (1995), Dobiesz et al. (2005), and Lake Huron Binational Partnership (2006).
Desired Future Status—GOOD: This rating is an educated guess based upon a low likelihood and limited public desire of reaching VERY GOOD status (the return on investment would likely decrease substantially in going from GOOD to VERY GOOD). Reaching an overall goal of GOOD is dependent upon continued reduction in phosphorus concentrations in Saginaw Bay and other high nutrient areas, as well as maintenance of low phosphorus areas throughout much of the northern portions of the lake.

CONDITION

KEA: Community architecture

Indicator: Abundance and distribution of invasive species

Description: Abundance and distribution of key aquatic invasive species that impact native community structure or function (e.g., sea lamprey, gobies, Dreissenids, others). This indicator reflects both new introduction rates, which can lead to further ecological and economic impacts to the Great Lakes, as well as the status of established invasive species. Reducing the impacts of invasive species on Nearshore Zone communities requires both the prevention of further introductions and the reduction of currently established species.

Basis for Assessing Indicator: These thresholds are a qualitative placeholder until more quantitative data and analyses are available. Improvement in the indicator rating requires prevention of new introductions and GOOD and VERY GOOD ratings require stable or reduced distribution and abundance of established species.

Current Status—FAIR: Currently, we have not adequately prevented the introduction of new invasive species because existing policies to control the introductions through ballast water and the pet trade are insufficient. However, ballast water standards are better than they once were. There are localized efforts to control emergent and submerged aquatic plants, but little has been done to control aquatic invasive species populations, except the regional control of sea lamprey and a few other short-term efforts (e.g., ruffe in Thunder Bay).

Desired Future Status—GOOD: Reaching an overall goal of GOOD is dependent upon strong policies to prevent introductions through ballast water, pet trade, and other significant vectors, as well as early detection-rapid response programs to try to prevent the initial establishment of introduced species, and integrated pest management projects to control problem species in select areas.

Indicator: Native fish species richness

Description: An index reflecting how well represented the full range of native species that would be anticipated to occur within a particular area. This is a comprehensive measure of the full suite of Great Lakes fish species, to reflect significant declines in native species.

Basis for Assessing Indicator: While data are currently unavailable to evaluate this indicator. Most work is fairly species-specific and there are basically no current sampling efforts at the 0-10 meter depth contour, where most of the fish diversity is found. This measure is likely to be a good surrogate for Nearshore Zone community structure and habitat integrity overall, and is more likely to be available than other comprehensive measures of biological integrity.

Current Status—FAIR: Currently, we do not have sufficient data assembled to rate this indicator with confidence. FAIR is was an educated guess because invasive species (e.g., gobies) still maintain a large proportion of the fish assemblage and many native species are not present in areas where they were known to occur historically. But native species have undergone some recovery in recent years (e.g., Schaefer et al. 2008), so this rating is certainly not POOR.

Desired Future Status—VERY GOOD: Reaching an overall goal of VERY GOOD is dependent upon the full range of habitats available in quality condition and key invasive species held in check.

<u>**Indicator: Lake sturgeon population five-year average yield**</u>

Description: The population average of lake sturgeon from all sources over the preceding five-year period for which information is available. Lake sturgeon are globally rare and are a good indicator of the health of the Nearshore Zone habitats and tributary connectivity. Maintaining populations of lake sturgeon is included in the Lake Huron Fish Community Objectives and this species is tracked by management agencies (DesJardine et al. 1995, Fielder et al. 2008).

Basis for Assessing Indicator: The current fish community metric states only that the species should be removed from its threatened status in U.S. waters and populations in Canada be maintained or rehabilitated. The Fish Community Objective was used as the cutoff between FAIR and GOOD. Additional cutoffs were developed based upon the need for restoration of lake sturgeon populations at representative locations around Lake Huron. More specific quantitative goals for these and identification of stratification units are still necessary.

Current Status—POOR: Rating based on expert opinion, supported by literature. Lake sturgeon spawn in only a few of the lake's tributaries (documented in five Ontario tributaries) and there is no population of significance in any tributary on the Michigan side (Fielder 2008). Lack of access to spawning habitat above dams and other barriers is the primary obstacle to recovery, combined with their inherent vulnerability as a long-lived species that only reaches reproductive maturity after 12 to 33 years (Hay-Chmielewski and Whelan 1997). The critical importance and limited availability of riverine spawning habitat for lake sturgeon likely impacts our understanding of other key threats limiting other life stages, such as juvenile rearing habitat. For example, *Hexagenia* have been shown to be preferred food items for lake sturgeon (Harkness and Dymond 1961, Hay-Chmielewski 1987, Chiasson et al. 1997), but this important prey item is nearly absent from Saginaw Bay where it was historically abundant.

Desired Future Status—VERY GOOD: Reaching an overall goal of VERY GOOD is dependent upon restoring strong, viable lake sturgeon populations within representative areas, stratified throughout Lake Huron.

<u>**Indicator: Smallmouth bass population relative abundance**</u>

Description: Relative abundance of smallmouth bass at representative locations throughout Lake Huron over the preceding five-year period for which information is available. Smallmouth bass are a good indicator of the health of Nearshore Zone habitat quality and food web structure. Sustaining populations of smallmouth bass at "recreationally attractive levels" is a Lake Huron Fish Community Objective (DesJardine et al. 1995, Fielder et al. 2008).

Basis for Assessing Indicator: Relative abundance and age composition is available for smallmouth bass at a limited number of locations throughout the basin. Capitalizing on this fact, indicator ratings were developed to reflect the health of smallmouth bass populations at these locations. Quantitative ratings still need to be developed.

Current Status—GOOD: This rating is based on discussion in Fielder et al. (2008).

Desired Future Status—VERY GOOD: Threats to smallmouth bass are not so insurmountable as to not be able to meet a VERY GOOD standard. Both quantitative indicator ratings and baseline conditions need to be determined.

Indicator: Walleye population five-year average

Description: Walleye population abundance across the lake over the preceding five-year period for which information is available. Walleye are an important native sport fish, a good indicator of Nearshore Zone health and tributary connectivity, and a top predator that plays an important role in the Nearshore Zone food web. Maintaining populations of walleye is included in the Lake Huron Fish Community Objectives and this species is tracked by management agencies (DesJardine et al. 1995, Fielder et al. 2008). Although yield is not the best indicator because of differential effort over time (Bence and Mohr 2008), data are not currently available to support a more robust indicator (e.g. catch per unit effort).

Basis for Assessing Indicator: The current fish community metric is based upon annual yield. The Fish Community Objective was used as the cutoff between FAIR and GOOD. Additional cutoffs were identified from historic (1885-1910 for GOOD-VERY GOOD cutoff) and recent (1950-2004 for POOR-FAIR cutoff) population levels (Figure 11 in Fielder et al. 2008).

Current Status—FAIR: Walleye annual yield was among the lowest ever recorded in the early 2000s (Fielder et al. 2008). However, strong year classes in 2003, 2004, and 2005 in Saginaw Bay (Fielder et al. 2007) have lead to angler catch rates for walleye that have not been seen in decades. If this trend continues, with similar increases elsewhere in Lake Huron, the Current Status for this indicator will improve relatively quickly. However, the population is unlikely to improve to near its potential until significant riverine spawning habitat is accessible (Fielder et al. 2008), especially on the U.S. side (Michigan Department of Natural Resources 2009).

Desired Future Status—GOOD: Reaching an overall goal of GOOD is dependent upon: restoring/maintaining high walleye population numbers in Saginaw Bay, restoring populations in Georgian Bay and other areas with high potential walleye habitat (e.g., Thunder Bay), and improving access to significant spawning rivers (Fielder et al. 2008).

Indicator: Yellow perch population five-year average yield

Description: Yellow perch population abundance across the lake the preceding five-year period for which information is available. Yellow perch are an important native sport fish, a good indicator of the health of the Nearshore Zone, including Coastal Wetlands, and—to a lesser extent than walleye and sturgeon—tributary connectivity. Maintaining populations of yellow perch is included in the Lake Huron Fish Community Objectives and this species is tracked by management agencies (DesJardine et al. 1995, Fielder et al. 2008). Although yield is not the best indicator because of differential effort over time (Bence and Mohr 2008), data are not currently available to support a more robust indicator (e.g. catch per unit effort).

Basis for Assessing Indicator: The current fish community metric is based upon annual yield. The Fish Community Objective was used as the cutoff between FAIR and GOOD. Additional cutoffs were identified from historic (1885-1915 for GOOD-VERY GOOD cutoff) and recent (1990-2004 for POOR-FAIR cutoff) population levels (Figure 11 in Fielder et al. 2008).

Current Status—POOR: Ratings are based on expert opinion, supported by literature. Yellow perch annual yield across Lake Huron was among the lowest ever recorded in the early 2000s (Fielder et al. 2008), including record lows in 2004 and 2005. Recent years have produced some strong year classes, but due to poor growth resulting in increased predation and poor young-of-year overwinter survival populations have not rebounded as expected.

Desired Future Status—GOOD: Reaching an overall goal of GOOD is dependent upon restoring high yellow perch population numbers in historically important areas such as the Les Cheneaux Islands, the North Channel, Georgian Bay, Lexington, southern Lake Huron Port, Saginaw Bay, Tawas, Pt. Austin, and Harbor Beach.

KEA: Food web linkages

Indicator: Mean densities of Hexagenia in softshore mesotrophic waters

Description: Densities of Hexagenia in mesotrophic waters with soft substrate in Lake Huron, particularly, but not limited to, Saginaw Bay. *Hexagenia spp.* are an important food source for many Nearshore Zone fishes (Harkness and Dymond 1961, Hay-Chmielewski 1987, Chiasson et al. 1997) and due to their large size and historic abundance, they likely played an important role in benthic processes.

Basis for Assessing Indicator: Indicator ratings are based on numbers from Edsall et al. (2005), and are highly conservative relative to density expectations discussed in Madenjian et al. (1998) for western Lake Erie. *Hexagenia* underwent a population crash in the 1950s, going from 63 m^{-2} in 1955, to 9 m^{-2} in 1956, to 1 m^{-2} in 1965 (Edsall et al. 2005). For the FAIR to GOOD cutoff, the 63 m^{-2} was selected, because this is a known historic density prior to that crash. However, *Hexagenia* densities were likely already severely depressed by 1955, so this is a very conservative cutoff for GOOD and a higher number was needed for a VERY GOOD rating. Since other historic data were unavailable for Saginaw Bay, and since Saginaw Bay was already quite impacted by 1955 and has similar physio-chemical conditions to Western Lake Erie, mean *Hexagenia* densities documented in Edsall et al. (2005) for Western Lake Erie soft substrates were used.

Current Status—POOR: At 28 stations sampled across Saginaw Bay by Edsall et al. (2005), *Hexagenia* were represented by a single nymph.
Desired Future Status—VERY GOOD: Western Lake Erie *Hexagenia* populations have largely recovered, hence it seems likely that the same could happen for Lake Huron. However, a better understanding of what is preventing *Hexagenia* recovery in Saginaw Bay that has not been an impediment in Western Lake Erie is needed. Once this is identified, feasibility may require the desired rating to drop.

Indicator: Mean densities of rotifers, copepods, and cladocerans in early summer

Description: Mean densities of rotifers, copepods, and cladocerans during early summer. Zooplankton are an important food source to virtually every Lake Huron fish species during at least one life stage.

Basis for Assessing Indicator: Indicator ratings are based upon zooplankton densities reported in a study in western Lake Erie (MacIsaac et al. 1995) comparing zooplankton densities pre and post introduction of zebra mussels. While western Lake Erie is not ideal for establishing Lake Huron benchmarks, rotifer surveys in Lake Huron in 1974 (Stemberger et al. 1979) were consistent with the MacIsaac et al. (1995) study in western Lake Erie, with rotifer densities along the Nearshore Zone of southern Lake Huron often exceeding 1000 ind. L^{-1}, especially in Saginaw Bay. Hence, ratings thresholds were set conservatively based on MacIsaac et al. (1995).

Current Status—POOR: This rating is very conservative and is a best-guess.

Desired Future Status—GOOD: With the introduction of Dreissenids, it is likely that VERY GOOD levels cannot be achieved.

KEA: Spawning habitat quality and accessibility

Indicator: Spawning/recruitment success of representative coastal wetland spawners
Description: This indicator represents spawning and/or recruitment success (depending upon data availability) of a suite of Nearshore Zone indicator species that spawn in Coastal Wetlands. The key indicator species are yellow perch, northern pike, and muskellunge (*Esox masquinongy*) due to data availability, but other species of interest include pugnose shiner (*Notropis anogenus*), lake chubsucker (*Erimyzon sucetta*), brassy minnow (*Hybognathus hankinsoni*), and spotted gar (*Lepisosteus oculatus*). Nearly all Great Lakes fish species utilize Coastal Wetlands for at least one life stage. Most of these use Coastal Wetlands for spawning; for many fish species Coastal Wetlands represent their primary Great Lakes spawning habitat. Maintaining populations of yellow perch, northern pike, and muskellunge are reflected in Lake Huron Fish Community Objective and these species are tracked by U.S. and Canadian management agencies (DesJardine et al. 1995, Fielder et al. 2008). Other fish species of interest that spawn in this habitat include pugnose shiner, lake chubsucker, brassy minnow, and spotted gar, which are each of some conservation concern in the region (Eagle et al. 2005), however additional efforts would be needed to include these species in this indicator.

Basis for Assessing Indicator: These thresholds are a qualitative placeholder until more quantitative data and analyses are available.

Current Status—FAIR: Yellow perch populations are well-below historic numbers and are not meeting the Fish Community Objective (Fielder et al. 2008). Similarly, northern pike numbers have declined substantially below levels observed in the 1980s and 90s in parts of Lake Huron and muskellunge are rare or absent from many areas (Fielder et al. 2008). Based upon the condition of these key indicators, a POOR rating could be justified for this indicator. However, there are still very important, high-quality Coastal Wetlands in Lake Huron that provide important fish-spawning habitat, and these populations are likely impacted by additional factors beyond coastal wetland habitat. Further degradation of these Coastal Wetlands would contribute to a POOR rating here.
Desired Future Status—GOOD: This rating is an educated guess based upon a low likelihood of reaching the VERY GOOD status. Reaching an overall goal of GOOD is dependent upon yellow perch populations returning to levels near those seen in the 1960's, and substantial increases in northern pike and muskellunge populations in appropriate habitats across the lake.

Indicator: Spawning/recruitment success of representative non-reef/non-wetland spawners
Description: Spawning and/or recruitment success (depending upon data availability) of indicator species that spawn or rear in Nearshore Zone gravel, sand, and cobble habitats. The key indicator species is smallmouth bass (*Micropterus salmoides*) due to data availability, but other species of interest include spoonhead sculpin (*Cottus ricei*), rock bass (*Ambloplites rupestris*), and emerald shiner (*Notropis anogenus*). The gravel, sand, and cobble Nearshore Zones represent a large portion of the Lake Huron Nearshore Zone, with a much larger area than Coastal Wetlands and nearshore reefs combined. Among species that primarily spawn in this habitat is the smallmouth bass; they generally spawn in gravel substrates (Lane et al. 1996). Maintaining populations of smallmouth bass at "recreationally attractive levels" is a Fish Community

Objective for Lake Huron (DesJardine et al. 1995) and this species is tracked by U.S. and Canadian management agencies (Liskauskas 2004, Fielder et al. 2008), though not through systematic long-term or lakewide monitoring. Other fish species of interest that spawn in this habitat include spoonhead sculpin and rock bass. Spoonhead sculpin are a Species of Greatest Conservation Need in Michigan (Eagle et al. 2005) and use coarser substrate for spawning (under boulders, cobble, or logs; Lane et al. 1996) than smallmouth bass; however, there is little effort to assess their status in Lake Huron—even locally. Rock bass are a fairly good indicator of habitat quality and they generally use somewhat coarser spawning substrate than smallmouth bass, though they have some overlap (under cobble, gravel, and logs; Lane et al. 1996). Rock bass are sometimes considered in localized surveys of other species (e.g., Gonder 2003). Emerald shiners spawn in similar, though somewhat finer, substrates (gravel and sand; Lane et al. 1996) and though there is not specific monitoring for this species, there resurgent abundance in the Lake Huron Nearshore Zone in recent years has caught the attention of researchers (Schaeffer et al. 2008).

Basis for Assessing Indicator: These thresholds are a qualitative placeholder until more quantitative data and analyses are available.

Current Status—GOOD: Smallmouth bass populations are generally in relatively high abundance in important areas such as Georgian Bay, Saginaw Bay, and the North Channel (Fielder et al. 2008). Rock bass population abundances have been more mixed, with good populations in Saginaw Bay and poor populations in Georgian Bay (Fielder et al. 2008). Emerald shiners populations have proliferated in Lake Huron in recent years, following the decline of alewife populations (Schaefer et al. 2008). In combination, Nearshore Zone (non-wetland) spawners have generally been doing GOOD in recent years, though some species' populations would be considered FAIR.

Desired Future Status—VERY GOOD: This rating is an educated guess based upon the potential for reaching VERY GOOD status. Reaching an overall goal of VERY GOOD will require improved conditions (e.g., sediment regimes) at some sites.

Indicator: Spawning/recruitment success for representative nearshore reef spawning species

Description: This indicator represents spawning and/or recruitment success (depending upon data availability) of a suite of Nearshore Zone indicator species that spawn on nearshore reefs. The key indicator species are lake herring (*Coregonus artedi*), lake trout, and lake whitefish due to data availability, but they are meant to represent other reef spawning species of interest. Nearshore reefs are critical habitat for lake herring, lake trout, and lake whitefish. These fish historically were ecologically and economically important to the Great Lakes, and significant in defining the uniqueness of native Great Lakes fish assemblages. Maintaining populations of each of these species are included in the Lake Huron Fish Community Objectives and these species are tracked by U.S. and Canadian management agencies (DesJardine et al. 1995, Bence et al. 2008, Ebener et al. 2008).

Basis for Assessing Indicator: These thresholds are a qualitative placeholder until more quantitative data and analyses are available.

Current Status—POOR: This rating is based on literature. Recruitment of lake whitefish improved to the GOOD range in the 1990s, up from POOR measures in the 1960s and '70s (Ebener et al. 2008). However, more recently there have been some indications of lake whitefish recruitment declining, likely due to the population crash in *Diporeia* spp.; recruitment of lake trout and lake herring is POOR (Bence et al. 2008, Ebener et al. 2008). There are recent signs of improvement in lake trout recruitment (Riley et al. 2007) indicating some potential to move this rating from POOR to FAIR, but currently recruitment for these indicators remains POOR.

Desired Future Status—GOOD: This rating is an educated guess based upon a low likelihood of reaching VERY GOOD status. Reaching an overall goal of GOOD is dependent upon improved lake whitefish recruitment to at least the 1990s levels, and substantial improvement in recruitment for lake herring and lake trout.

4.3c Islands

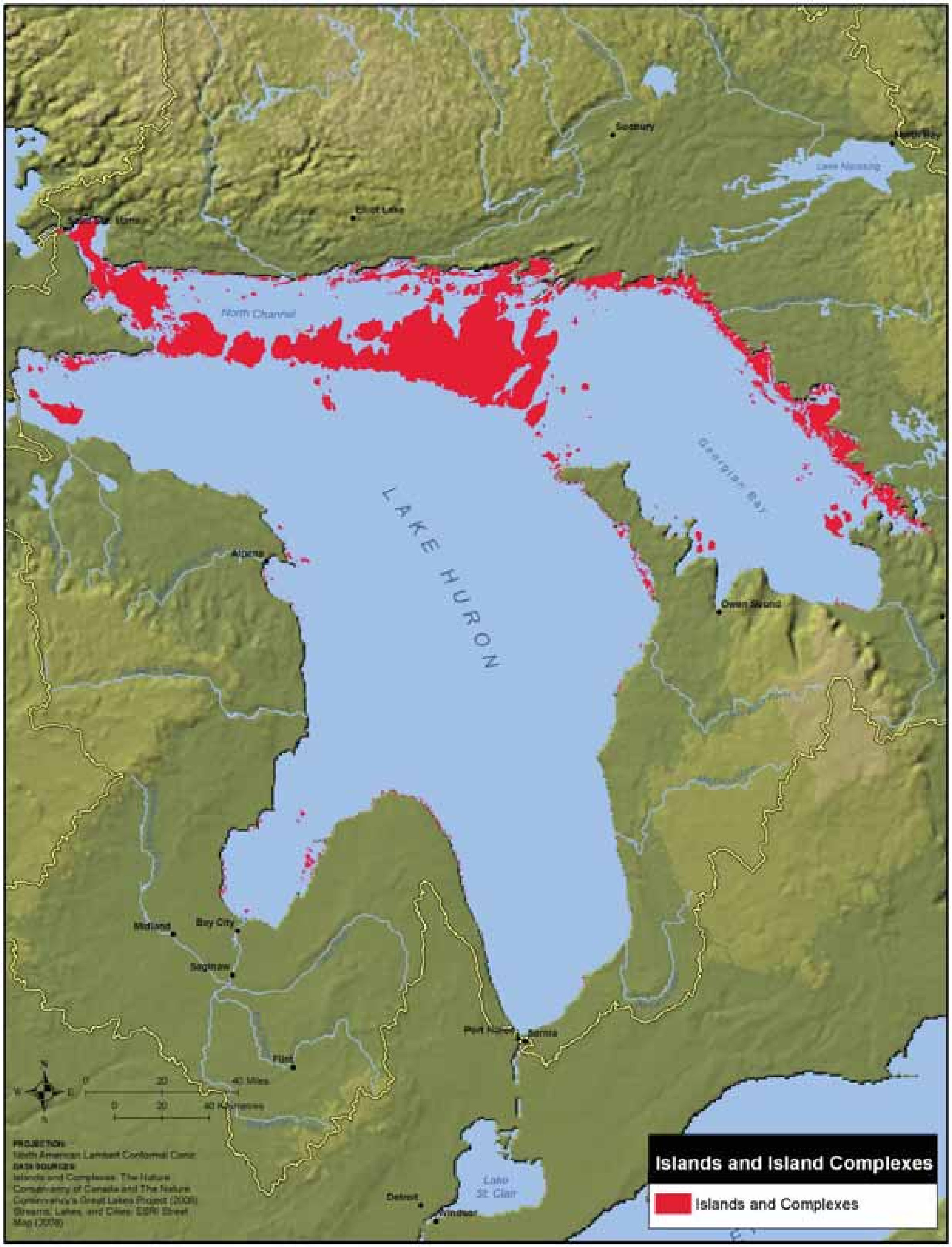

Figure 7: Map of the island biodiversity feature.

Islands are land masses within Lake Huron that are surrounded by water. This feature includes both natural and artificial islands (e.g. breakwalls), and over 23,000 islands and island groups have been identified in Lake Huron (Figure 7; Kraus et al. 2009). However, the number, extent and configuration of many islands, particularly small, low-lying ecosystems, is very dynamic depending on lake-levels. Artificial islands are included in this feature because they can be important for colonial nesting waterbirds. Islands in Lake Huron can be divided into three general groups: 1) limestone and dolostone islands associated with and surrounding Manitoulin and Drummond Islands and the Bruce Peninsula, 2) dense archipelagos of small nearshore Precambrian Shield islands in eastern Georgian Bay and the North Channel and, 3) small groups of low-erodible islands in Saginaw Bay.

Islands are an integral part of the biophysical character of Lake Huron, and are important to the lake's biodiversity. From the archipelagos of eastern Georgian Bay to the low-lying, erodible islands of Saginaw Bay, these islands harbor many notable biodiversity features. Due to their isolation, strong coastal influence and unique geology, Lake Huron's Islands support many rare ecological communities including coastal fens, alvars, bedrock and cobble lakeshores. Collectively, Lake Huron Islands are well known to be important sites for nesting colonial waterbirds (Wires & Cuthbert 2001), for species and communities endemic to or largely limited to the Great Lakes (Henson et al. 2010, and for disjunct species and communities, especially those from western North America (Guire and Voss 1963) and the Atlantic coastal plain (Jalava et al. 2005). Other specialized habitats that contribute to biodiversity include key stopover sites for migratory landbirds and spawning areas for fish (Ewert et al. 2004).

The Islands of Lake Huron are relatively young. Many were part of, or connected to, the mainland following the last period of glaciation when water levels were lower. However, during the Lake Nipissing stage (approximately 4000 years ago), isostatic rebound and changes in outflows caused water levels to rise about 8 meters above present-day levels before receding again (Karrow and Calkin 1985). Islands with lower relief were submerged during this period, and then emerged as water levels receded to present day levels. In most regions of Lake Huron, Islands are still slowly emerging as the land continues to rebound from glaciations, and, in recent years, due to lower water levels. Colonization of most Islands by mainland flora and fauna has therefore occurred in the last few thousand years. Many Islands harbor plant and animal communities that are different from the mainland due to their isolation and unique disturbance regimes. For example, many of the smaller Islands around Manitoulin have very unstable plant communities due to changing lake levels, limited immigration, and colonial nesting waterbirds (Morton & Venn 2000). Many Islands do not have natural populations of white-tailed deer (*Odocoileus virginianus*) resulting in much greater abundance of plants that deer find palatable, such as Canada yew (*Taxus canadensis*), and creating vegetation structure that is uncommon on the mainland (Ewert et. al 2004). Although Islands are rarely free of invasive species, some Islands have relatively low numbers of invasive species and thus provide excellent examples of communities that are characteristic of the Great Lakes region.

The Great Lakes Islands Biodiversity project (Henson et al. 2010) recently identified key Islands for conservation based on an assessment of biodiversity values, threat, and existing conservation. Some of the key Islands identified are: Manitoulin Island, Great La Cloche Island, Dorcus Bay island complex, Charity Island, Bois Blanc Island and the American Camp Island complex. Islands in the northern part of Lake Huron and Georgian Bay generally have a greater level of protection and better condition with fewer threats.

Indicators for the Islands feature were not geographically stratified for this assessment. As Islands include other biodiversity features (e.g. Nearshore Zone, Coastal Wetlands, Coastal Terrestrial Systems), attributes for these features can also be used for Islands. The following attributes focus on indicators that are island-specific, and not covered by other biodiversity features.

Nested Biodiversity Conservation Features

- colonial nesting waterbirds
- globally rare species, vegetation communities and ecosystems
- migratory bird stopover habitat

Summary of Viability

The Islands biodiversity feature of Lake Huron has a viability status of GOOD, overall, owing to ratings GOOD for both condition and size categories (Table 3). This rating is based on an assessment of five indicators, two related to condition and three related to size (Table 6).

The condition KEA is *Disturbance*, and both indicators are related to threats—one a composite index, currently rated as GOOD, and the other an index of deer browse that is currently rated as FAIR. The size KEAs are all related to birds, not because those are the only important attributes but because data on birds are much more comprehensive than for other organisms or structural components. Islands are key for both breeding and migrating birds, and criteria for assessing their significance are well developed (Ewert et al. 2004, Henson et al. 2010).

Table 6: KEAs and indicators for the Islands biodiversity feature.

KEAs and Indicators for Islands						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Condition	Disturbance	Average composite threat ranking	>2	>1.5 - 2	***>1 - 1.5***	1
	Disturbance	Browse index	>50% of stems are browsed, seedling hedged, <15 cm tall	**>50% of stems are browsed, seedlings hedged, 15 cm ≤ saplings ≤ 180 cm**	*>50% of stems are browsed, seedlings not hedged 15 cm ≤ sapling ≤ 180 cm*	1-50% of stems are browsed
Size	Population size & dynamics (size)	Consistency of colonial waterbird use	No known use (suitable habitat)	Irregular use (1-2 times/ decade)	***Regular use (3-4 times / decade)***	Consistent use (2-3 times since the 1970s or consistently during the 1990s

KEAs and Indicators for Islands						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Size cont.	Population size & dynamics (size)	Numbers of colonial nesting waterbirds (Herring & Ring-billed Gulls)	TBD	TBD	***>1000 Herring Gulls*** ***> 10,000 Ring-billed Gulls***	TBD
	Population size & dynamics (size)	Productivity of colonial waterbird nests	TBD	TBD	***>25% of nest produce 1+ fledglings***	TBD

LANDSCAPE CONTEXT

KEA: Disturbance

Indicator: Average composite threat ranking

Description: A threat index score has been assigned to all Islands and Islands complexes in Lake Huron as part of the Great Lakes Islands Biodiversity project (Henson et al. 2010). The index includes presence and proximity to pits and quarries, distance to mining claims, road densities (primary secondary and tertiary roads), building densities (number of buildings per island or island complex) and the percent of island or island complex converted to cropland.

Basis for Assessing Indicator: The threats scores are based on quantitative measures of land use and land cover.

Current Status—GOOD: There is great variation in the threat index score for Lake Huron Islands. Islands in Georgian Bay and the North Channel have scores that range from 0-52, while Islands in the southern portion had a range of 1-22. In general, large, nearshore islands with road and ferry access are the most threatened and have the least amount of protected areas (e.g., Manitoulin Island). Several large privately-owned islands that are isolated have very low threat scores, such as Great Duck, Cockburn, Philip and Fitzwilliam. Some larger islands that are protected have relatively high threat scores (e.g., Flowerpot Island and Beausoleil Island) due to existing recreational infrastructure.
Desired Future Status— GOOD: It is feasible to maintain a GOOD status. This is based on expert opinion.

Indicator: Deer Browse Index

Description: Percentage of tree stems browsed. High populations of white-tailed deer (*Odocoileus virginianus*) can have significant impacts on vegetation composition and structure on Islands (Ewert et al. 2004). Deer populations on Lake Huron Islands include natural occurrences on many of the larger islands.

Islands that support deer can be especially vulnerable to over-browsing because of limited food supplies. Assessing the level of browse on Canada yew and northern white-cedar is a good survey technique (Jackson 2006).This indicator cannot be mapped, as it requires field surveys.

Basis for Assessing Indicator: Based on Jackson (2006).

Current Status—FAIR: Many of Lake Huron's Islands do not have white-tailed deer, and these Islands may support examples of vegetation communities that are rare on the mainland. In most northern regions, deer populations are limited by natural predation and winter die-offs, and over-browsing is not an issue. Some private Islands have very high numbers of deer that were both introduced and are fed in the winter. These sites have high browse damage.
Desired Future Status—GOOD: This rating is a based on the need, and ability, to limit deer numbers on southern Islands.

SIZE

KEA: Population size & dynamics

Indicator: Consistency of colonial waterbird use
Description: Number of years nesting site is used per decade. One of the key functions Islands provide in Lake Huron is their use as breeding habitat for colonial nesting waterbirds. A high proportion of the region's gull and tern species nest on natural or artificial islands in the Great Lakes and forage on fish in the lakes (Zeran et al. 2009). These indicators consider the population size and consistency of use of Islands by colonial nesting waterbirds. These indicators are based on the report by Wires and Cuthbert (2001) and Ewert et al. (2004). Several Islands and island groups have been identified as Important Bird Areas (IBAs) because of their importance to colonial nesting waterbirds.

Basis for Assessing Indicator: Regular use shows lack of disturbance to nesting sites and maintenance of suitable habitats in feeding areas.

Current Status—GOOD: Many of Lake Huron's Islands that support large numbers of colonial nesting waterbirds are consistently used. Many of these have been designated as IBAs and highlighted in waterbird plans (e.g., Zeran et al. 2009). Regular and comprehensive waterbird monitoring is conducted in Canada and the U.S.
Desired Future Status—GOOD: It is likely that maintaining the GOOD rating is feasible.

Indicator: Number of colonial nesting waterbirds
Description: Number of Herring and Ring-billed Gulls at each site. Large populations indicate a lack of disturbance to nesting sites and maintenance of suitable habitats in feeding areas.

Basis for Assessing Indicator: Thresholds still need to be determined; more research is needed.

Current Status—GOOD: There are many Islands with large numbers of both species. Approximately 144,000 Ring-billed Gulls occur on the Islands in the northern portion of Lake Huron (Zeran et al. 2009). Population

numbers at most sites have been consistent in the last decade (Zeran et al. 2009). Regular and comprehensive waterbird monitoring is conducted in Canada and the U.S.
Desired Future Status—GOOD: It is likely that maintaining the GOOD rating is feasible.

<u>Indicator: Productivity of colonial nesting waterbirds</u>
Description: Number of nestlings fledge per nest. This indicator is also linked to lack of disturbance and availability of food.

Basis for Assessing Indicator: Thresholds still need to be determined; more research is needed.

Current Status—GOOD: This indicator is linked to overall population size. Monitoring has shown that most colonials have successful fledging.
Desired Future Status—GOOD: It is likely that maintaining the GOOD rating is feasible.

4.3d Native Migratory Fish

Native Migratory Fish are fish that move to rivers, Nearshore Zones or wetlands to spawn (Environ 2008). For the purpose of the Lake Huron Biodiversity Conservation Strategy, we have limited our definition of Native Migratory Fish to those that spawn in rivers, including lake sturgeon, walleye and sucker species. The Nearshore Zone feature and Coastal Wetlands feature address the viability of species that spawn in wetlands or Nearshore Zone environments such as northern pike and yellow perch.

Lake sturgeon (*Acipenser fulvescens*), the largest freshwater fish in the Great Lakes, were found in all the Great Lakes historically and, especially in Lake Erie but also in Lake Huron, existed in large numbers (Trautman 1957). Sturgeon are characterized as ancient fish, almost unchanged from fossils dating back 100 million years (USGS 2009). Adult lake sturgeon prefer the Nearshore Zone environment, and are considered a warmwater species. They eat small invertebrates including larval insects, crayfish, snails, clams, and leeches (U.S. Fish and Wildlife Service (USFWS) 2009). The Erie-Huron corridor played a central role for these fish in the Great Lakes supporting populations making them one of the most abundant fish species in Lake Huron and Lake Erie (USGS 2009). By 1900, lake sturgeon were greatly reduced in number due to overfishing, pollution, and loss of access to spawning habitat. For example, populations were reduced by 80% in Lake Erie in 1900 (USFWS 2009). Remnant populations remain in Lake Huron, with spawning evident in tributaries of the North Channel (including Garden, Mississaugi, and Spanish Rivers), Georgian Bay (Nottawasaga River) and Saginaw Bay (Rifle River) (EC and EPA 2009 and A. Liskauskas, pers. comm.). Lake sturgeon are listed as threatened by the American Fisheries Society, and listed as Endangered, Threatened or Special Concern in 19 of the 20 states in its range (USFWS 2009). In Michigan they are listed as state threatened.

Walleye (*Sander vitreus*) are also well distributed throughout the Great Lakes and Lake Huron, yet have decreased abundance based on 37 populations that are routinely sampled (Fielder et al. in press). Similar to lake sturgeon, walleye populations were adversely effected by habitat destruction, overfishing, barriers to spawning habitat, and more recently aquatic invasive species such as alewife (Fielder et al. in press). To address this dramatic reduction, walleye are stocked in many locations throughout Lake Huron. However in Saginaw Bay—where walleye are most abundant—stocking has recently ceased with a resurgence in natural reproduction by walleye, likely due to a crash in alewife abundance (Fielder, pers. comm.).

There are eight species of suckers known in Lake Huron (Desjardine et al. 1995). Based on observational information, sucker species appear to be abundant throughout Lake Huron; however, we elected to include these species as little data are collected or analyzed for these species and we recommend filling this data gap for a number of reasons. Suckers, as migratory animals, play an important role in the transport of nutrients and energy in the food chain of tributary streams. Suckers are not and probably never will be a management target. Nonetheless, they are emblematic of a suite of native fishes that has historically used Great Lakes tributaries for breeding. Today, sucker runs are by far the largest of breeding runs in almost all Great Lakes tributaries. Ongoing work by P.B. McIntyre and J.D. Allan demonstrates that the importance of these runs extends well beyond the fish themselves (Pete McIntyre pers. comm.). The sucker run delivers a large and sustained nutrient pulse to tributary streams at exactly the time when they need it most--just before leaf-out, when the water is warm enough to support strong algal and insect growth. These nutrients are rapidly transferred into stream food webs, enhancing invertebrate production that feeds fish, birds, and bats. Camera traps show that bears, eagles, and other native scavengers eagerly search out sucker carcasses in streams. Billions of sucker larvae come pouring back out into the lakes each year, where they are important prey for game fish. Taken together, sucker runs are an essential natural process supporting the productivity of low-nutrient streams, which includes numerous tributaries of Lake Huron. The impressive size of contemporary runs shows that these fish are resilient to much environmental degradation, but barriers to the lake-stream connection have and will result in starving the upstream reaches of critical inputs carried by Native Migratory Fishes like suckers.

Indicators for Native Migratory Fish were geographically stratified to reflect significant differences among the five generally recognized basins of Lake Huron (Figure 4).

Nested Biodiversity Conservation Features

- lake sturgeon (*Acipenser fulvescens*)
- walleye (*Sander vitreus*)
- lake trout (*Salvelinus namaycush*)
- coaster brook trout (*Salvelinus fontinalis*)
- suckers and redhorse (Catostomidae)
- pike (including muskellunge, Esocidae)
- burbot (*Lota lota*)
- native lamprey (Petromyzontidae)
- yellow perch (*Perca flavescens*)

Summary of Viability

The Native Migratory Fish biodiversity feature of Lake Huron has a viability status of FAIR, overall, owing to ratings FAIR for landscape context and POOR for size (Table 3). This rating is based on an assessment of twenty indicators, five related to landscape context and fifteen related to size (Table 7).

The landscape context indicators all relate to the KEA of *Access to Spawning Areas*, stratified by the five basins described in the introduction. These range in current status from GOOD (in Georgian Bay) to POOR (in Saginaw Bay). The primary information used to derive these status ratings are maps and knowledge of dams and other barriers to migration. The indicators of size relate to population sizes of the three nested features—lake sturgeon, walleye, and sucker species. The lake sturgeon indicator also considers whether there is known natural reproduction in each of the five basins. Lake sturgeon populations are POOR everywhere except in the North Channel (FAIR), which is also the only basin that has produced evidence of natural reproduction. Sucker populations are considered to be in GOOD condition throughout the lake, and walleye populations are considered mostly FAIR, except in Saginaw Bay where there are GOOD populations and healthy reproduction.

Table 7: KEAs and indicators for the Native Migratory Fish biodiversity feature.

KEAs and Indicators for Native Migratory Fish						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context	Access to Spawning Areas	Kilometers of Accessible Quality Habitat--Georgian Bay	Spawning habitat is severely limiting population size	Spawning habitat is limiting population size	***Sufficient spawning habitat to maintain population***	Spawning habitat quantity within historic range of variation
	Access to Spawning Areas	Kilometers of Accessible Quality Habitat--Main Basin	Spawning habitat is severely limiting population size	**Spawning habitat is limiting population size**	*Sufficient spawning habitat to maintain population*	Spawning habitat quantity within historic range of variation
	Access to Spawning Areas	Kilometers of Accessible Quality Habitat--North Channel	Spawning habitat is severely limiting population size	**Spawning habitat is limiting population size**	*Sufficient spawning habitat to maintain population*	Spawning habitat quantity within historic range of variation
	Access to Spawning Areas	Kilometers of Accessible Quality Habitat--Saginaw Bay	**Spawning habitat is severely limiting population size**	Spawning habitat is limiting population size	*Sufficient spawning habitat to maintain population*	Spawning habitat quantity within historic range of variation
	Access to Spawning Areas	Kilometers of Accessible Quality Habitat--St. Marys River	Spawning habitat is severely limiting population size	**Spawning habitat is limiting population size**	*Sufficient spawning habitat to maintain population*	Spawning habitat quantity within historic range of variation
Size	Population size & dynamics (size)	Number mature lake sturgeon--North Channel	Below number for self-sustaining population; extremely limited evidence of reproduction	**Below number for self-sustaining population; moderate evidence of natural reproduction**	*Sufficient mature adults for self-sustaining population; good evidence of natural reproduction*	Size of population and reproduction are within historic range of variation

KEAs and Indicators for Native Migratory Fish						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Size cont.	Population size & dynamics (size)	Number of mature lake sturgeon--Georgian Bay	**Below number for self-sustaining population; extremely limited evidence of reproduction**	Below number for self-sustaining population; moderate evidence of natural reproduction	*Sufficient mature adults for self-sustaining population; good evidence of natural reproduction*	Size of population and reproduction are within historic range of variation
	Population size & dynamics (size)	Number of mature lake sturgeon--Main Basin	**Below number for self-sustaining population; extremely limited evidence of reproduction**	Below number for self-sustaining population; moderate evidence of natural reproduction	*Sufficient mature adults for self-sustaining population; good evidence of natural reproduction*	Size of population and reproduction are within historic range of variation
	Population size & dynamics (size)	Number of mature lake sturgeon--Saginaw Bay	**Below number for self-sustaining population; extremely limited evidence of reproduction**	Below number for self-sustaining population; moderate evidence of natural reproduction	*Sufficient mature adults for self-sustaining population; good evidence of natural reproduction*	Size of population and reproduction are within historic range of variation
	Population size & dynamics (size)	Number of mature lake sturgeon--St. Marys River	**Below number for self-sustaining population; extremely limited evidence of reproduction**	Below number for self-sustaining population; moderate evidence of natural reproduction	*Sufficient mature adults for self-sustaining population; good evidence of natural reproduction*	Size of population and reproduction are within historic range of variation
	Population structure & recruitment	Abundance and composition of suckers--Georgian Bay	Populations below sustainable levels	Vulnerable to population decline	***Sufficient for long term persistence***	Numbers and diversity within historic levels
	Population structure & recruitment	Abundance & composition of suckers--Main Channel	Pops below sustainable levels	Vulnerable to population decline	***Sufficient for long term persistence***	Numbers & diversity w/in historic levels

KEAs and Indicators for Native Migratory Fish						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Size cont.	Population structure & recruitment	Abundance and composition of suckers--North Channel	Populations below sustainable levels	Vulnerable to population decline	***Sufficient for long term persistence***	Numbers and diversity within historic levels
	Population structure & recruitment	Abundance and composition of suckers--Saginaw Bay	Populations below sustainable levels	Vulnerable to population decline	***Sufficient for long term persistence***	Numbers and diversity within historic levels
	Population structure & recruitment	Abundance and composition of suckers--St. Marys River	Populations below sustainable levels	Vulnerable to population decline	***Sufficient for long term persistence***	Numbers and diversity within historic levels
	Population structure & recruitment	Abundance, natural reproduction of walleye--Georgian Bay	Populations below sustainable levels	**Vulnerable to population decline**	*Sufficient for long term persistence*	Numbers and diversity within historic levels
	Population structure & recruitment	Abundance, natural reproduction of walleye--Main Basin	Populations below sustainable levels	**Vulnerable to population decline**	*Sufficient for long term persistence*	Numbers and diversity within historic levels
	Population structure & recruitment	Abundance, natural reproduction of walleye--North Channel	Populations below sustainable levels	**Vulnerable to population decline**	*Sufficient for long term persistence*	Numbers and diversity within historic levels
	Population structure & recruitment	Abundance, natural reproduction of walleye--Saginaw Bay	**Populations below sustainable levels**	Vulnerable to population decline	*Sufficient for long term persistence*	Numbers and diversity within historic levels
	Population structure & recruitment	Abundance, natural reproduction of walleye--St. Marys River	Populations below sustainable levels	**Vulnerable to population decline**	*Sufficient for long term persistence*	Numbers and diversity within historic levels

LANDSCAPE CONTEXT

KEA: Access to Spawning Areas

Indicator: Kilometers of accessible quality habitat

Description: Measure of the length of tributaries that are accessible to Lake Huron and of sufficient quality for spawning by fish that must migrate to spawn. This indicator is a measure of available habitat for a key life stage of Native Migratory Fish.

Basis for Assessing Indicator: Access to quality spawning habitat is key to maintaining sturgeon populations. However, the amount of available spawning habitat is not currently quantified, nor has the amount needed. While the decline of sturgeon is correlated to the loss of connectivity to spawning habitat (Hay-Chmielewski and Whelan 1997), the amount of restoration of that connectivity is not known. Data sets that would enable quantitative thresholds include: accurate locations of barriers, habitat mapping, and habitat requirements.

Current Status—FAIR: This rating varies significantly by sub-basin. Georgian Bay has the only GOOD rating, the Main Basin, North Channel, and St. Marys River were all rated as FAIR, and Saginaw Bay was rated as POOR. Rating is based on expert opinion. Overall in Lake Huron, only 13 km of an estimated 250 km of mainstem river are currently accessible due to barriers (Liskauskas et al. 2007).
Desired Future Status—GOOD: This rating is an educated guess based on the current trend in dam removal.

SIZE

KEA: Population size & dynamics

Indicator: Number of mature lake sturgeon

Description: The number of individual lake sturgeon mature enough to spawn, coupled with the amount of evidence for natural reproduction. This indicator is key to the long-term persistence of lake sturgeon and is an indicator of potential reproductive success.

Basis for Assessing Indicator: The rating groupings for this indicator are qualitative placeholders, given that little data are available (Hay-Chmielewski and Whelan 1997). More data on locations and spawners are needed.

Current Status—POOR: There is an exception to this overall ranting; there is some evidence of natural reproduction in the North Channel, so that basin is rated as FAIR. Otherwise the populations in the rest of the lake are at remnant levels. Currently, the actual number of spawning adults is known only for two populations (www.fws.gove/midwest/sturgeon/index.htm).
Desired Future Status—GOOD: This rating is an educated guess based upon the low likelihood of reaching VERY GOOD status.

KEA: Population structure & recruitment

Indicator: Abundance and composition of suckers

Description: Number of individuals of each migratory sucker species. This indicator represents a placeholder for a data gap. Data on sucker abundance and composition are not collected consistently and have not been analyzed for status and trends.

Basis for Assessing Indicator: The rating groupings for this indicator are qualitative placeholders, given that little data are available. Information across the basin is needed for suckers.

Current Status—GOOD: Based on expert opinion, it appears that there is no issue with sucker abundance; however analysis of unpublished data sources could be done to provide greater certainty.
Desired Future Status—GOOD: It is feasible to maintain the rating of GOOD; but would take considerable new effort to upgrade to a VERY GOOD rating.

Indicator: Abundance and natural reproduction of walleye

Description: Numbers of individuals that are naturally reproducing. Walleye are a managed, stocked species in much of the basin (Fielder, et al. in press)—though stocking levels vary in response to amount of naturally occurring reproduction. It is important to the long-term persistence of walleye that the population be abundant and naturally reproducing.

Basis for Assessing Indicator: Currently, data on yield are collected, giving some indication of population robustness, but is also complicated by catch effort. A direct measure of reproductive success and population abundance would provide a better measure here. Thus, the ratings for this indicator are qualitative placeholders.

Current Status—FAIR: For the most part, while walleye are naturally reproducing in all parts of Lake Huron, their abundance is low. The exception is in Saginaw Bay, where reduced abundances of alewife appear to be allowing for higher abundance of walleye (D. Fielder, pers. comm.). Saginaw Bay is thus rated as GOOD.
Desired Future Status—GOOD: This rating is an educated guess based upon the low likelihood of reaching VERY GOOD status without significant additional effort.

4.3e Coastal Wetlands

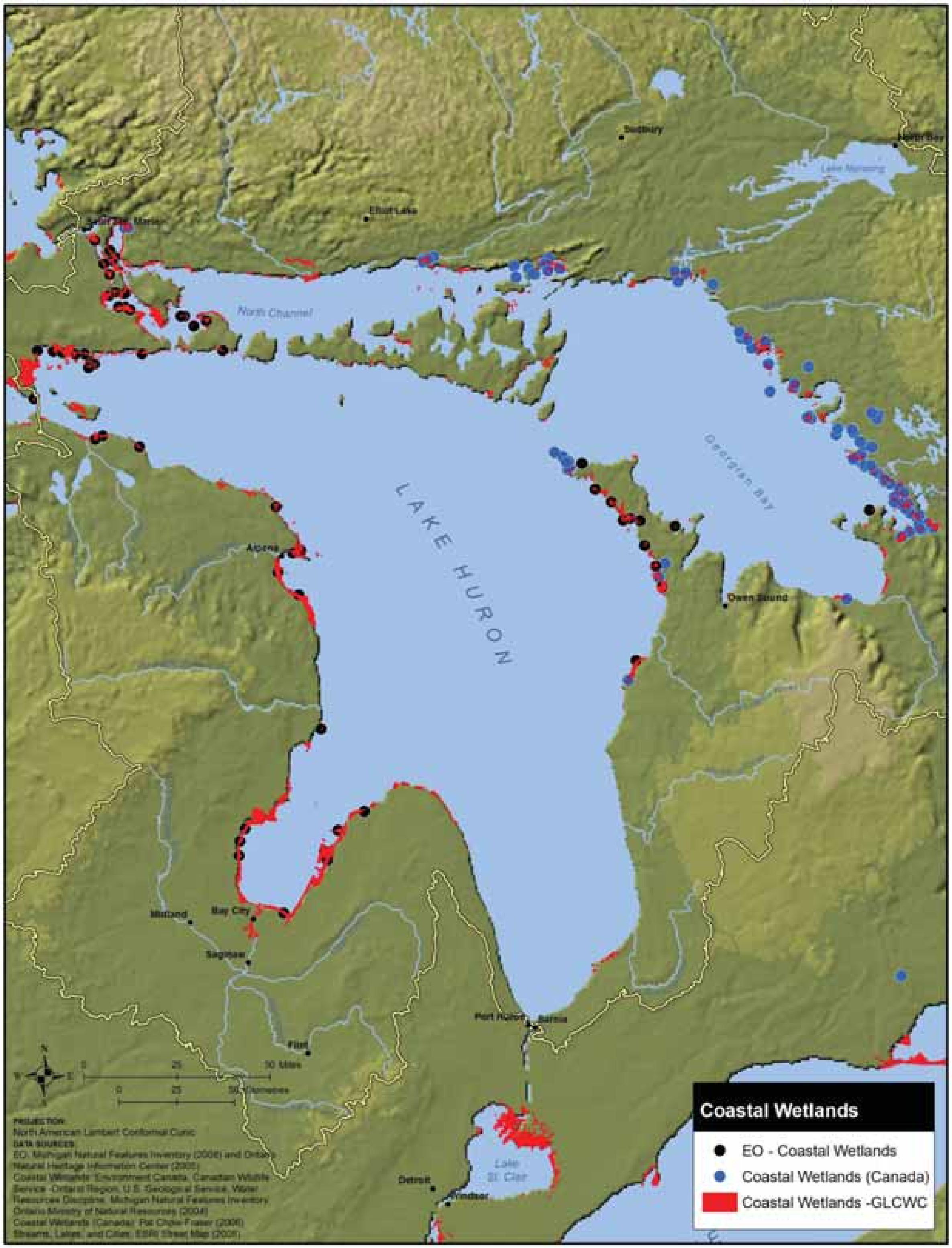

Figure 8: The Coastal Wetlands biodiversity feature. Note: Wetland element occurrences (EOs) are under-represented, especially in Georgian Bay and on the eastern shore of Lake Huron, due to a lack of spatial data.

The Coastal Wetlands feature includes all hydrogeomorphic types of wetlands (lacustrine, riverine, barrier protected, plus sub-categories including estuaries and island coastal wetlands) with hydrologic connectivity to, and directly influenced by, Lake Huron (Figure 8). For this assessment, Coastal Wetlands include emergent wetlands that extend into the Nearshore Zone feature up to a depth of 3 m; there is spatial overlap between these two biodiversity features, but each warrants individual focus for biodiversity conservation. This feature also includes some nested features (such as coastal fens) that also appear as nested features for the Coastal Terrestrial Systems feature. Where specific wetland communities (such as coastal fens or sedge meadows) are not hydrologically connected to Lake Huron, they would be considered part of the Coastal Terrestrial Systems feature.

Coastal Wetlands are intermediate zones linking the open waters of the Great Lakes with their watersheds. They are dominated by large lake processes, including water level fluctuations, wave action, and wind tides or seiches. Coastal wetland productivity is a source of nutrients and organic material for the lake food web. These wetlands sustain large numbers of common or regionally rare bird, mammal, herptile and invertebrate species, including many land-based species that feed in the highly productive marshes. Many Great Lakes fish species depend upon Coastal Wetlands for some portion of their life cycles. They serve as staging and feeding areas for migratory birds. Periodic inundation during high lake levels re-sets succession and maintains the highly productive herb-dominated ecosystem. Though many Coastal Wetlands in northern Lake Huron remain in very good condition, in southern Lake Huron and a few other areas where the natural ecosystems have been highly modified, vegetated Coastal Wetlands persist only because of intensive management. Due to this distinct difference with regard to modification and degradation, indicators for several KEAs were stratified between southern and northern Lake Huron.

As a conservative estimate, Coastal Wetlands of Lake Huron account for 64,641 ha (159,663 acres) which is almost 30% of the total wetland area for all five Great Lakes (Chow-Fraser 2009). Georgian Bay is one of the world's largest freshwater archipelagos, and wetland habitat is prevalent along the highly complex shoreline especially throughout the eastern coast. This region is host to a disproportionately large number of pristine wetlands, with high biodiversity of plants and animals (Chow-Fraser 2006, Croft and Chow-Fraser 2007, Seilheimer and Chow-Fraser 2006). Even so, Georgian Bay and other portions of northern Lake Huron are prone to the same anthropogenic stressors as southern Lake Huron, which has been affected by human growth for a much longer time and to a greater degree. Research by McMaster University shows that incremental cottage development along with an expanded road network has resulted in eutrophication and ecological damage to wetlands of southeastern Georgian Bay, even without the conventional stressors related to large-scale land-use alterations (e.g. industrial, agricultural or urban activities).

There is a strong and significant link between anthropogenic stressors (i.e. urbanization and agricultural development) and degradation of Coastal Wetlands (Chow-Fraser 2006, Danz et al. 2007, Morrice et al. 2007, Trebitz et al. 2007). Established indicators of cultural degradation include percentage of altered land (Chow-Fraser 2006), human population density (Danz et al. 2007, Morrice et al. 2007), and road density (Danz et al. 2007) – factors that tend to increase concentrations of nutrients and suspended solids in natural ecosystems. In response to the growing concern over eutrophication, ecological indices have been developed to track and monitor the habitat quality of Great Lakes coastal waters (e.g., Minns et al. 1994, Lougheed and Chow-Fraser 2002, Wilcox et al. 2002, McNair and Chow-Fraser 2003, Uzarski et al. 2005, Seilheimer and Chow-Fraser 2006, Niemi et al. 2009).

There is need for a comprehensive geospatial assessment of the extent and distribution of Coastal Wetlands across all of Lake Huron. Such an assessment would provide a sampling "frame" from which particular sites could be selected for ground based assessment and monitoring. It also could provide estimates of various types of wetlands and how they may change over time. A wetland inventory that consists of maps and statistics can also provide a reference to assist local, state, Aboriginal groups, and federal agencies in evaluating projects for which they have permitting and oversight responsibilities. This is most practical using aerial photography and satellite sensors to generate wetland inventories. Recurring remote sensing assessments can also provide a means to monitor wetland loss, hydrologic alterations, changes to physical habitat condition and other types of wetland change.

The Great Lakes Environmental Indicator (GLEI) landscape study is the only comprehensive approach that has synthesized a set of spatially delineated variables into categories of anthropogenic stress (agriculture, atmospheric deposition, human population, land cover, and point source pollutants) to produce a cumulative index of anthropogenic stress (Danz et al. 2007). The study demonstrated a strong spatial patterning in landscape-scale stressors and related them to variation in fish, amphibian, bird, water quality and other indicators to build landscape-based stress response models. This was completed for the U.S. basin and similar efforts are needed for the Canadian basin to develop landscape indicators.

Though many Coastal Wetlands in northern Lake Huron remain in very good condition, in southern Lake Huron and a few other areas where the natural ecosystems have been highly modified, vegetated Coastal Wetlands persist only because of intensive management. Due to this distinct difference with regard to modification and degradation, indicators for several KEAs were stratified between southern and northern Lake Huron (see section 4.1 Methodology).

Nested Biodiversity Conservation Features

- emergent marshes, wet meadows, sedge communities, and fens
- migratory waterbirds
- wetland obligate nesting birds
- eastern fox snake (*Elaphe vulpine gloydi*)
- queen snake (*Regina septemvittata*)
- submergent/ emergent/ floating native aquatic plants
- all esocids (members of the genus *Esox* including pike, pickerel, and muskellunge)
- other wetland dependent fishes
- aquatic macroinvertebrates

Summary of Viability

The Coastal Wetlands biodiversity feature of Lake Huron has a viability status of FAIR, overall, owing to ratings FAIR for both landscape context and condition and a rating of GOOD for the size category (Table 3). This rating is based on an assessment of thirteen indicators, seven related to landscape context, four related to condition and two related to size (Table 8).

Landscape context KEAs include *Connectivity among communities and ecosystems* and *water quality*, the former being indicated by percentage natural land cover in three zones—watershed, 0-2 km from the lake, and 2-5 km from the lake (each also stratified by northern and southern Lake Huron basins). Current status ratings for these indicators are mostly GOOD, except for the 2-5 km zone in southern Lake Huron (POOR) and the watershed land cover of southern Lake Huron (FAIR). The *water quality index (WQI) for wetland quality* is a composite water quality indicator and is rated as GOOD lakewide. Condition KEAs all relate to composition or habitat quality for nested features including wetland-spawning migratory fish (FAIR), wetland fish (GOOD), marsh birds (FAIR), and macrophytes (GOOD). The size of Coastal Wetlands was evaluated in relative terms and the current area was judged as GOOD.

Table 8: KEAs and indicators for the Coastal Wetlands biodiversity feature.

KEAs and Indicators for Coastal Wetlands						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context	Connectivity among communities and ecosystems	Percent natural land cover in watershed--northern Lake Huron	<40%	40-60%	**>60-80%**	*>80%*
	Connectivity among communities and ecosystems	Percent natural land cover in watershed--southern Lake Huron	<40%	**40-60%**	*>60-80%*	>80%
	Connectivity among communities and ecosystems	Percent natural land cover within 2 km of shoreline in northern Lake Huron	<20%	20-40%	**>40-70%**	*>70%*
	Connectivity among communities and ecosystems	Percent natural land cover within 2 km of shoreline in southern Lake Huron	<20%	20-40%	***>40-70%***	>70%
	Connectivity among communities and ecosystems	percentage of area 2-5 km from lake that is in natural land cover in northern Lake Huron	<40% natural cover	40 - 60% natural cover	**60 - 80% natural cover**	*80%+ natural cover*
	Connectivity among communities and ecosystems	percentage of area 2-5 km from lake that is in natural land cover in southern Lake Huron	**<40% natural cover**	*40 - 60% natural cover*	60 - 80% natural cover	80%+ natural cover

KEAs and Indicators for Coastal Wetlands						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context cont.	Water quality	Water Quality Index (WQI) for wetland quality	WQI of -3 to -1	WQI of -1 to 0	***WQI of 0 to 1***	WQI of 1 to 3
Condition	Abundance and diversity of wetland-dependent bird species	Marsh Bird IBI	0-2.5	**2.6-5.0**	*5.1-7.5*	7.6-10.0
	Fish Habitat Quality	Wetland Fish Index (WFI) of wetland quality	< 2.5	2.5 - 3.25	***3.25 - 3.75***	> 3.75
	Spawning habitat quality and accessibility	Spawning/recruitment success of representative coastal wetland spawners (key indicators are yellow perch, northern pike, muskellunge)	Very little recruitment, so that populations are severely declining or being maintained at levels much lower than historic range	**Some recruitment, but populations are in decline or are being maintained at levels well below the historic range**	*Good recruitment so that populations are increasing or being maintained at levels near the historic range-of variability*	Recruitment is maintaining populations well w/in historic range-of-variability or is increasing abundance toward historic range
	Species composition / dominance	Wetland macrophyte index	<2 or =2	3	***4***	5
Size	Size / extent of characteristic communities / ecosystems	Total area of all wetlands--northern Lake Huron	greater loss from current status	some percentage loss from current status	***Current area***	historic area
	Size / extent of characteristic communities / ecosystems	Total area of all wetlands--southern Lake Huron	greater loss from current status	some percentage loss from current status	***Current area***	historic area

LANDSCAPE CONTEXT

KEA: Connectivity among communities and ecosystems

Indicator: Percent natural land cover in watershed

Description: Percentage natural land cover in northern and southern Lake Huron. Watershed land use and the corresponding land cover has been shown to have an effect on water quality and basic functioning and resilience of ecological systems (Lougheed et al. 2001, Uzarski et al. 2005, Niemi et al. 2009). The presence, abundance and richness of several amphibian species is positively correlated with increasing extent and distance of forest cover from a wetland and negatively associated with road traffic/density (Houlahan and Findlay 2003, Eigenbrod et al. 2008). Presence and proximity of land cover in the vicinity of Coastal Wetlands provides a broad scale surrogate for ecosystem function, hydrological connection, and habitat suitability and vulnerability. A similar indicator is used in the Nearshore Zone assessment, but it is focused on the contributing watershed to the Nearshore Zone reach.

Basis for Assessing Indicator: The ratings used here are based on expert opinion as there are no direct association between extent of land cover and general wetland health and function. The relationship between natural cover and functions of Coastal Wetlands need to be verified, and measures validated through field sampling data. More research is needed.

Northern:
Current Status—GOOD: This rating is based on a GIS assessment with a current measurement of roughly 65% natural.
Desired Future Status—VERY GOOD: Achieving this rating is a feasible goal.

Southern:
Current Status—FAIR: Land cover in southern Lake Huron has been heavily converted from natural land use. This rating is based on a GIS assessment which provided a result of roughly 50%.
Desired Future Status—GOOD: Achieving this rating will likely require substantial restoration efforts.

<u>**Indicator: Percent natural land cover within 2 km of shoreline**</u>
Description: Percentage of land within 2 km of the lake that is in natural land cover in northern and southern Lake Huron. The literature indicates that alteration of natural land cover within Coastal Terrestrial Systems (ex. coastal forests or grasslands) may have a significant impact on the Nearshore Zone and coastal aquatic habitat and its inhabitants and on water quality and quantity within the watershed (SOLEC, nearshore areas of the Great Lakes 2008, C. Kenneth Dodd Jr. and Lora L. Smith 2003).
This indicator is also used for the Nearshore Zone and Coastal Terrestrial Systems assessment.

Basis for Assessing Indicator: See rationale for watershed land cover above.

Northern:
Current Status—GOOD: Rating is based on a GIS assessment that produced a measurement of 61.5%.
Desired Future Status—VERY GOOD: This rating could be feasible to achieve, given the focus on protection of shoreline areas.

Southern:
Current Status—GOOD: Land use in the coastal zone in southern Lake Huron has been moderately converted to non-natural land cover, based on a rapid visual assessment. This rating is based on a GIS assessment that produced a measurement of 53.7%.
Desired Future Status—GOOD: This rating seems feasible to maintain.

Indicator: Percentage of area 2-5 km from lake that is in natural land cover

Description: Percentage of land between 2 and 5 km of the lake that is in natural land cover in northern and southern Lake Huron. This zone is important to Coastal Wetlands both as a buffer and as connected habitat.

Basis for Assessing Indicator: See rationale for watershed land cover above.

Northern:
Current Status— GOOD: Rating is based on a GIS assessment that produced a measurement of 79.7%.
Desired Future Status—VERY GOOD: This zone may be the most vulnerable to conversion—it is likely to be less protected by zoning and legislative restrictions—so the feasibility of maintaining a VERY GOOD rating may be lower than in other zones.

Southern:
Current Status—POOR: Land cover in this zone in southern Lake Huron has been heavily converted from natural land cover. This rating is based on a GIS assessment that produced a measurement of 38.1%.
Desired Future Status—FAIR: Given the current status and obstacles for increasing natural land cover in this region, FAIR is likely the most realistic future goal.

KEA: Water quality

Indicator: Water Quality Index (WQI) for wetland quality

Description: The Water Quality Index (WQI) score provides a snapshot of coastal wetland condition according to the degree of anthropogenic disturbance and is reflected by enrichment of nutrients and suspended solids in the water column, as well as conductivity and temperature (Chow-Fraser 2006). Over 200 Great Lakes Coastal Wetlands have been surveyed between 1998 and 2008 using this method.

Basis for Assessing Indicator: This Water Quality Index (Chow-Fraser 2006) has been widely applied to Great Lakes Coastal Wetlands producing accurate measurements of condition. The WQI uses 12 parameters to rank the quality of wetlands from the most degraded to the most undisturbed sites and has been used throughout the five Great Lakes. WQI scores use the following parameters: water turbidity, total suspended solids (mg/L), total inorganic suspended solids (mg/L), total phosphorus (μg/L), soluble reactive phosphorus (μg/L), total ammonium nitrogen (μg/L), total nitrate nitrogen (μg/L), total nitrogen (μg/L), specific conductance (μS/cm), temperature (°C), and algal chlorophyll a (μg/L). For the purpose of this report, P. Chow-Fraser agreed to modify the original six categories of disturbance and provided ratings to represent sites that are most to least undisturbed.

Current Status—GOOD: This snapshot of wetland conditions across the Lake Huron basin (Figure 9) shows that few of the Georgian Bay and Lake Huron sites were in degraded condition. Sites deemed to be in excellent or reference condition were only found in Georgian Bay. Wetlands that show signs of "moderate degradation" are in southeastern Georgian Bay. Canadian portions of Lake Huron and Georgian Bay were associated with high mean WQI scores which corresponded to an overall VERY GOOD condition. Moderately degraded (FAIR) sites occur within Saginaw Bay and northwestern Lake Huron.
Desired Future Status—GOOD: Given that this indicator is currently rated as GOOD, it seems feasible to maintain.

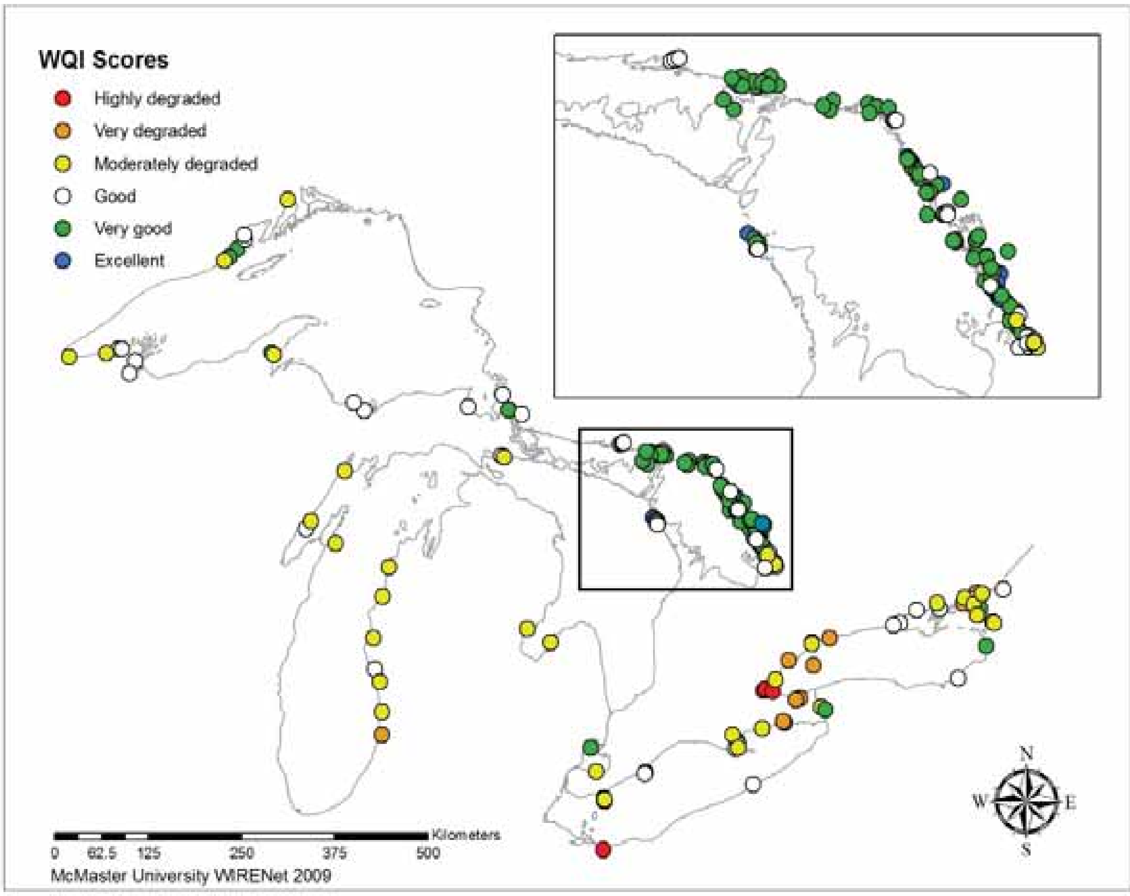

Figure 9: Distribution of wetlands and their associated ecological condition as determined by the Water Quality Index. Inset map is of Georgian Bay.

CONDITION

KEA: Abundance and diversity of wetland-dependent bird species

Indicator: Marsh Bird Index of Biotic Integrity (IBI)
Description: The marsh bird index incorporates data on 23 species of birds. This indicator is based on recent development of quality indices using multiple taxonomic groups (Niemi et al. 2009).

The indicator presented in this section is a result of the GLEI indicator development process and represents an index of biological condition for breeding bird communities corresponding to land use. The surveys were completed for Michigan wetlands only, and reports on coastal wetland bird communities, rather than wetland obligate marsh nesting species which may provide a better index of wetland condition. Additional work is necessary to harmonize indicators and extend capture conditions in the North Channel and Georgian Bay.

Basis for Assessing Indicator: The ratings simply represent a division of the scale of the IBI into quartiles—there may be a more appropriate way to segregate the ratings into categories.

Current Status—FAIR: Data from 69 sites on Lake Huron result in an overall rating of 4.88.
Desired Future Status—GOOD: The current status is close enough to a GOOD that it seems reasonable to expect that through restoration efforts, coupled with further surveys, a GOOD rating could be achieved.

KEA: Fish habitat quality

Indicator: Wetland Fish Index (WFI) of wetland quality

Description: The WFI is a measurable indicator of fish species composition in Coastal Wetlands but also considers ecosystem function because environmental variables (water quality) are incorporated into the index. Fish assemblages have been used as land use or water quality indicators of environmental conditions at the Great Lakes coastal margins (Seilheimer and Chow-Fraser 2006, Uzarski et al. 2005). Despite the responses of fish to disturbance and other environmental gradients, more among-site variation in fish indicator scores is accounted for by wetland hydrogeomorphic and wave energy within the Nearshore Zone (P. Chow-Fraser, pers. comm., Chow-Fraser 2009).

Basis for Assessing Indicator: The wetland fish index (WFI) and associated scores are derived from the statistical relationships of biotic communities along a gradient of deteriorating water quality. The relative sensitivity of this biotic index was tested at Great Lakes wetlands relative to the Water Quality Index (Seilheimer and Chow-Fraser 2006) and found to have a significant ($r2 = 0.75$, $P < 0.0001$) and significant positive relationships with the Water Quality Score.

Current Status—GOOD: WFI scores were high in Georgian Bay 3.67 and Lake Huron 3.6. (Seilheimer and Chow-Fraser 2006)
Desired Future Status—GOOD: With recent attention to management and restoration of coastal marshes, maintenance of a GOOD score seems a reasonable goal.

KEA: Spawning habitat quality and accessibility

Indicator: Spawning/recruitment success of representative coastal wetland spawners

Description: This indicator represents spawning and/or recruitment success (depending upon data availability) of a suite of Nearshore Zone indicator species that spawn in Coastal Wetlands. The key indicator species are yellow perch, northern pike, and muskellunge (*Esox masquinongy*) due to data availability, but other species of interest include pugnose shiner (*Notropis anogenus*), lake chubsucker (*Erimyzon sucetta*), brassy minnow (*Hybognathus hankinsoni*), and spotted gar (*Lepisosteus oculatus*). Nearly all Great Lakes fish species utilize Coastal Wetlands for at least one life stage. Most of these use Coastal Wetlands for spawning; for many fish species Coastal Wetlands represent their primary Great Lakes spawning habitat. Maintaining populations of yellow perch, northern pike, and muskellunge are reflected in Lake Huron Fish Community Objective and these species are tracked by U.S. and Canadian management agencies (DesJardine et al. 1995, Fielder et al. 2008). Other fish species of interest that spawn in this habitat include pugnose shiner, lake chubsucker, brassy minnow, and spotted gar, which are each of some conservation concern in the region (Eagle et al. 2005), however additional efforts would be needed to include these species in this indicator.

Basis for Assessing Indicator: These thresholds are a qualitative placeholder until more quantitative data and analyses are available.

Current Status—FAIR: Yellow perch populations are well-below historic numbers and are not meeting the Fish Community Objective (Fielder et al. 2008). Similarly, northern pike numbers have declined substantially below levels observed in the 1980s and 90s in parts of Lake Huron and muskellunge are rare or absent from many areas (Fielder et al. 2008). Based upon the condition of these key indicators, a POOR rating could be justified for this indicator. However, there are still very important, high-quality Coastal Wetlands in Lake Huron that provide important fish-spawning habitat, and these populations are likely impacted by additional factors beyond coastal wetland habitat. Further degradation of these Coastal Wetlands would contribute to a POOR rating here.
Desired Future Status—GOOD: This rating is an educated guess based upon a low likelihood of reaching the VERY GOOD status. Reaching an overall goal of GOOD is dependent upon yellow perch populations returning to levels near those seen in the 1960's, and substantial increases in northern pike and muskellunge populations in appropriate habitats across the lake.

KEA: Species composition / dominance

Indicator: Wetland macrophyte index
Description:
Wetland macrophytes are directly influenced by water quality and impairment in wetland quality can be reflected by taxonomic composition of the aquatic plant community. A wetland macrophyte index (WMI) was derived from the statistical relationships of biotic communities along a gradient of deteriorating water quality and using plant presence/absence data for 127 coastal wetlands from all five Great Lakes (Croft and Chow-Fraser 2007).

Basis for Assessing Indicator: When the relative sensitivity of this biotic index was tested in 32 Great Lakes wetlands relative to the Water Quality Index, the WMI had significant positive relationships ($r2 = 0.84$; $P < 0.0001$) with the Water Quality Index. A major advantage of using the WMI is that this index focuses on taxa (submergent, floating, and emergent) found in open water areas of wetlands and plant species related to fish habitat. It can therefore be used to track the impact of human-induced disturbances and its effect on fish habitat in Coastal Wetlands. To quantify the extent to which WMI scores accurately reflected water quality conditions, Croft and Chow-Fraser (2007) regressed the WMI scores against corresponding WQI scores for 176 wetland-years from their large database which had both water quality and plant information. They found a highly significant linear relationship between the two indices ($r2 = 0.57$, $P < 0.01$), indicating good correspondence between the presence/absence of plants and water quality conditions, and hence human disturbance. The authors calculated a range of WMI scores roughly equivalent to the six categories of water quality conditions. For the purpose of this Strategy, however, Chow-Fraser provided scores that correspond to four indicator categories. Wetlands with WMI scores < 2.5 can be considered impaired (moderately to highly degraded conditions) and may require restoration and other management interventions. By contrast, wetlands with scores > 2.5 can be considered in GOOD to VERY GOOD condition.

Current Status—GOOD: The most pristine wetlands are located in the remote areas of eastern Georgian Bay and the North Channel which are associated with the lowest concentrations of nutrients and suspended solids (over half of the wetlands of Georgian Bay, and many of those in Lake Huron were in the VERY GOOD category). The higher WMI scores associated with eastern Georgian Bay are primarily reflective of the degree of human impact, not regional differences in geology or climate. When wetlands of Georgian Bay

were subjected to disturbance from agricultural and recreational activities, they acquired plant species indicative of human-induced disturbance encountered in wetlands of the two lower lakes.
Desired Future Status—GOOD: With increasing attention to conservation and restoration of wetlands and water quality, maintaining a GOOD rating is a feasible goal.

SIZE

KEA: Size / extent of characteristic communities / ecosystems

Indicator: Total area of all wetlands
Description: This indicator represents the total acres of wetlands in northern and southern Lake Huron. Wetlands have, in some parts of the lake, been destroyed by human activities including shoreline alteration, dredging, construction of jetties and marinas, and others, but there are no references that cite the amount of coastal wetland loss relative to the natural area.

Basis for Assessing Indicator: The current thresholds are qualitative placeholders, until more quantitative measures can be developed. More research is needed.

Current Status—GOOD: The current area of wetlands was determined to be within the acceptable range of variation for northern and southern Lake Huron.
Desired Future Status—GOOD: The likelihood of restoring wetlands to equal the historic area is quite low, so the current rating seems feasible and adequate to maintain.

4.3f Coastal Terrestrial Systems

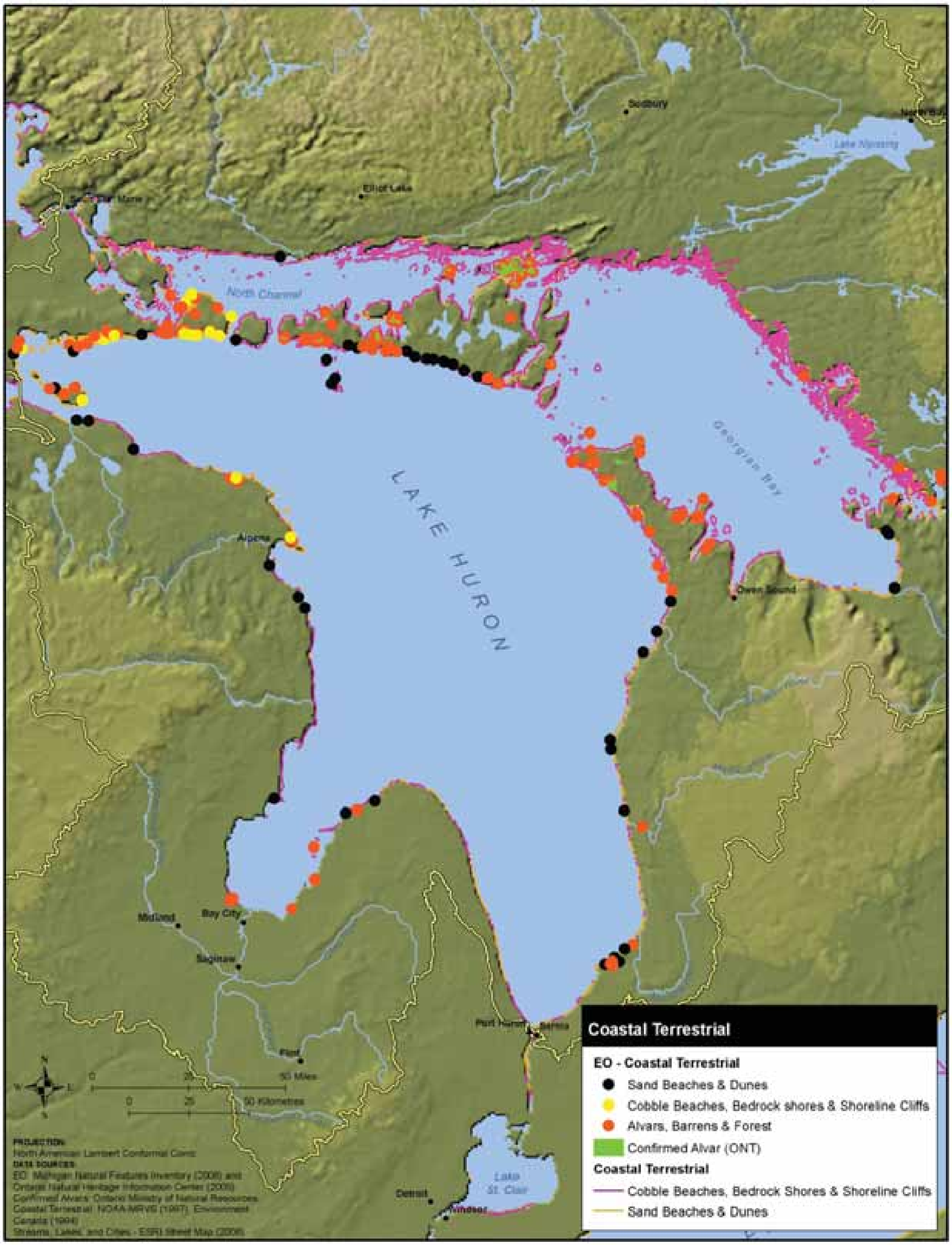

Figure 10: Map of the Coastal Terrestrial Systems biodiversity feature.

The Coastal Terrestrial System feature includes upland and wetland natural communities extending from the shoreline up to 2 km inland or to the extent of the (delineated) Great Lake coastal communities (Figure 10). These areas are inextricably linked to the biodiversity and health of Nearshore Zone waters, and contribute to the transfer of biomass and sediments into Lake Huron. This dynamic environment provides critical habitat for migratory birds (SOLEC 2008), and in some areas, supports endemic and globally rare species. In areas where there is shoreline development or other modification, the health of Coastal Terrestrial Systems and Nearshore Zone environments may be significantly impacted, causing changes to aquatic habitats, nutrient cycles, physical processes, and species assemblages including fish populations and richness (SOLEC 2008, Dodd and Smith 2003).

As with Aerial Migrants and Coastal Wetlands, the viability assessment for the Coastal Terrestrial Systems feature was geographically stratified for northern and southern Lake Huron (see section 4.1 Methodology). This division represents a significant climatic transition for terrestrial and coastal wetland vegetation that also is reflected in land use and thus habitat value for Aerial Migrants. This stratification resulted in much better distinction in the viability assessment without substantially increasing the level of effort required.

Nested Biodiversity Conservation Features

- sand beaches
- foredunes
- coastal back dune complexes (swales and ridges)
- bedrock shores
- cobble beaches
- shoreline cliffs / bluffs
- lake plain prairies
- Atlantic coastal plain disjunct communities
- coastal fens
- shoreline alvars
- coastal rock barrens
- Great Lakes coastal forests
- karst associated communities
- migratory stopover sites for shorebirds and landbirds (songbirds, raptors)
- coastal grassland
- piping plover (*Charadrius melodus*)
- Pitcher's thistle (*Cirsium pitcheri*)
- Hill's thistle (*Cirsium hillii*)

Summary of Viability

The Coastal Terrestrial Systems biodiversity feature of Lake Huron has a viability status of FAIR, overall, owing to ratings FAIR for both landscape context and condition and a rating of GOOD for the size category (Table 3). This rating is based on an assessment of fourteen indicators, four related to landscape context, eight related to condition and two related to size (Table 9).

Landscape context KEAs include *coastal land use*, and *connectivity among communities and ecosystems*. The percentage of natural land cover 2-10 km from the lake is the land use indicator and is rated as GOOD in northern Lake Huron and FAIR in southern Lake Huron. Road density, rated as FAIR and Poor in northern and southern Lake Huron, respectively, is the indicator of connectivity. Condition KEAs also include *community architecture*, *condition of nested features*, and *soil/sediment stability and movement* (all of which are stratified by northern and southern Lake Huron). Native plant cover indicates the first KEA and is ranked as GOOD (north) and FAIR (south); EO ranks, averaged in each basin, are used to indicate the condition of nested features and are rated GOOD and FAIR, respectively. Soil and sediment processes are characterized by two indicators—one an artificial shoreline hardening index and one related to the number of bed load traps and groins. Shoreline hardening is rated as VERY GOOD in both the northern and southern portions of the lake, and bed load traps and groins exist in numbers that result in a GOOD rating in both basins.

Table 9: KEAs and indicators for the Coastal Terrestrial Systems biodiversity feature.

KEAs and Indicators for Coastal Terrestrial Systems						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context	Coastal land use	percentage of area 2-10 km from lake that is in natural land cover in northern Lake Huron	<40% natural cover	40 - 60% natural cover	***60 - 80% natural cover***	80%+ natural cover
	Coastal land use	percentage of area 2-10 km from lake that is in natural land cover in southern Lake Huron	<40% natural cover	**40 - 60% natural cover**	*60 - 80% natural cover*	80%+ natural cover
	Connectivity among communities & ecosystems	road density (m road / km2) – northern Lake Huron	>2,000	***1,250 - 2,000***	500 - 1,250	<500
	Connectivity among communities & ecosystems	road density (m road / km2) – southern Lake Huron	**>2,000**	*1,250 - 2,000*	500 - 1,250	<500
Condition	Community architecture	Native plant cover-- northern Lake Huron	Dominated by invasive non-native and opportunistic native species	Dominated by non-native species with some invasive, mainly opportunistic native species	***Dominated by native species with some non-natives and invasive spp.***	Dominated by native species, including conservative species, few non-natives

KEAs and Indicators for Coastal Terrestrial Systems						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Condition cont.	Community architecture	Native plant cover--southern Lake Huron	Dominated by invasive non-native and opportunistic native species	***Dominated by non-native species with some invasive, mainly opportunistic native species***	Dominated by native species with some non-natives and invasive spp.	Dominated by native species, including conservative species, few non-natives
	Condition of nested features	EO ranks of selected nested features, northern Lake Huron	<30% A or B ranked	30-50% A or B ranked	***>50-70% A or B ranked***	>70% A or B ranked
	Condition of nested features	EO ranks of selected nested features, southern Lake Huron	***<30% A or B ranked***	30-50% A or B ranked	>50-70% A or B ranked	>70% A or B ranked
	Soil / sediment stability & movement (condition)	Artificial Shoreline Hardening Index--northern Lake Huron	>40%	30 - 40%	20 - 30%	***<20%***
	Soil / sediment stability & movement (condition)	Artificial Shoreline Hardening Index--southern Lake Huron	>40%	30 - 40%	20 - 30%	***<20%***
	Soil / sediment stability & movement (condition)	Bed load traps and groins (number of structures per length of shoreline)--northern Lake Huron	>300 structures/ 100 km shoreline	>200 - 300 structures/ 100 km shoreline	***30 - 200 structures/ 100 km shoreline***	<30 structures/ 100-km shoreline
	Soil / sediment stability & movement (condition)	Bed load traps and groins (# of structures per length of shoreline)--southern Lake Huron	>300 structures/ 100 km shoreline	**>200 - 300 structures/ 100 km shoreline**	*30 - 200 structures/ 100 km shoreline*	<30 structures/ 100-km shoreline

KEAs and Indicators for Coastal Terrestrial Systems						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Size	Size / extent of characteristic communities / ecosystems	Percent natural land cover within 2 km of shoreline in northern Lake Huron	<20%	20 - 40%	**>40 - 70%**	*>70%*
	Size / extent of characteristic communities / ecosystems	Percent natural land cover within 2 km of shoreline in southern Lake Huron	<20%	20 - 40%	***>40 - 70%***	>70%

LANDSCAPE CONTEXT

KEA: Coastal land use

Indicator: Percentage of area 2-10 km from lake that is natural land cover

Description: The percentage of undeveloped land within 2 and 10 km from the shoreline in northern and southern Lake Huron. The literature indicates that alteration of natural land cover within Coastal Terrestrial Systems (e.g., coastal forests or grasslands) may have a significant impact on the Nearshore Zone habitat and its inhabitants and on water quality and quantity within the watershed (SOLEC 2008, Dodd and Smith 2003).

Basis for Assessing Indicator: We adopted the same indicator rankings that were used in the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009), which were based on information from the following articles and organizations: Dodd and Smith 2003, Findlay and Lenton, 2001, Rubbo and Kiesecker 2005, and Environment Canada and the Central Lake Ontario Conservation Authority.

Northern:
Current Status—GOOD: This rating is based on a GIS assessment that produced a measurement of 61.5%.
Desired Future Status—GOOD: Given that the current status is near the lower end of the GOOD category, it is not likely that the rating can be improved in the foreseeable future.

Southern:
Current Status—FAIR: This rating is based on a GIS assessment that produced a measurement of 53.7%.
Desired Future Status—GOOD: This rating is based on expert opinion regarding the likelihood of reaching a GOOD status given that significant restoration efforts would be needed.

KEA: Connectivity among communities & ecosystems

<u>Indicator: Road density (km road / km2)</u>
Description: The concentration of roads in northern and southern Lake Huron basin. Existing information indicates that the U.S. and Canada are spanned by extensive road networks that have substantial ecological impacts (disrupting wildlife movements, modifying habitats, altering water drainage patterns, introducing exotic species, modifying microclimates and the chemical environment) on the surrounding lands, including coastal areas. These roads can be precursors to future impacts, because they facilitate land development and the further expansion of the road network itself (Ritters and Wickham 2003).

Basis for Assessing Indicator: We adopted the same indicator rankings that were used in the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009); these were based on information from the following articles and organizations: Ritters and Wickman 2003 (* defined FAIR-GOOD threshold) and EOMF 2006 (FAIR-GOOD threshold based on wide-ranging mammals).

Northern:
Current Status—FAIR: This rating is based on a GIS assessment that produced a measurement of 1,975.4 m road per km^2.
Desired Future Status—FAIR: This rating is based on expert opinion regarding the likelihood of the road density remaining the same.

Southern:
Current Status—POOR: This rating is based on a GIS assessment that produced a measurement of 2,853.2 m road per km^2.
Desired Future Status—FAIR: This rating is desired though may not be feasible given the dramatic reduction in road density that would be required.

CONDITION

KEA: Community architecture

<u>Indicator: Native plant cover</u>
Description: Vegetation dominated by native species within northern and southern Lake Huron. Expert opinion suggests that invasive vegetation pose a threat to native vegetation (Pauchard et al. 2009 and Martin et al. 2009).

Basis for Assessing Indicator: For this indicator, we adopted the same rankings that were used in the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009), which were based on Floristic Quality Assessment thresholds developed from Oldham, Bakowsky and Sutherland (1995), and Wilhelm and Ladd (1988).

Northern:
Current Status—GOOD: This rating is based upon expert opinion.
Desired Future Status—GOOD: Based on the likelihood of maintaining the current status of GOOD status. This rating is based on expert opinion but can be validated with analysis.

Southern:
Current Status –FAIR: This rating is based upon expert opinion.
Desired Future Status –FAIR: Based on the likelihood of maintaining the current status.

KEA: Condition of nested targets

Indicator: Element Occurrence (EO) ranks of selected nested features
Description: The element occurrence ranks (provincial/state) are used to set protection priorities for species and natural communities within northern and southern Lake Huron (see the list of nested features in the introduction of the Coastal Terrestrial Systems section). These ranks are used by the Natural Heritage Information Centre (NHIC) Ontario Ministry of Natural Resources and the Michigan Natural Features Inventory (MNFI), Michigan State, to set protection priorities for rare species and natural communities. Some ranks do have legal designations and some do not.

Basis for Assessing Indicator: This indicator is based on onsite assessment by the Ontario Ministry of Natural Resources (OMNR) Staff, in Ontario Canada and the Michigan Natural Features Inventory (MNFI) and MDNRE.

Northern:
Current Status—GOOD: This rating is based upon expert opinion.
Desired Future Status—GOOD: Based on the likelihood of maintaining the current status of GOOD.

Southern:
Current Status—POOR: This rating is based upon expert opinion.
Desired Future Status—POOR: This rating is based on limited opportunity to re-establish rare populations and expert opinion.

KEA: Soil / sediment stability & movement

Indicator: Artificial Shoreline Hardening Index
Description: Percent of shoreline protected with artificial structures (e.g., sea walls, rip rap) to prevent erosion. Shoreline hardening alters Great Lakes Nearshore Zone processes, habitat quality, and community structure (Meadows et al. 2005). In fact, experts generally feel that the impacts of shoreline hardening have been underestimated in the Great Lakes, relative to other threats like degraded water quality (Scudder Mackey, pers. comm.). This indicator is also used in the Nearshore Zone assessment.

Basis for Assessing Indicator: Data to inform thresholds for shoreline hardening in the Great Lakes are difficult to obtain. We adopted the same indicator rankings utilized in the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009), which were loosely based upon a shoreline hardening SOLEC indicator (EC and EPA 2007, p. 315-317). This approach will provide consistency and comparability between plans, given that no additional data have been identified to suggest alternative indicator rankings.

Northern:
Current Status—VERY GOOD: The rating is based on NOAA-GLERL data (GLERL 1997) as presented in SOLEC 2009 (EC and EPA 2009), which describe 3.1% of Lake Huron coastal units as >70% hardened, 1.1% as 40-70% hardened, 4.5% as 15-40% hardened, and 91% as <15% hardened (total of 10.6% hardened). However, experts in the Nearshore Zone working group estimated that Lake Huron's shoreline is 30-40% hardened, suggesting that major areas of the lake have been hardened and therefore the average hardened area is probably a little over 30%. This discrepancy and the experts' sense that the degradation caused by altered shorelines merits something other than a "Very Good" rating suggest two things: 1) that further analyses are needed to better rank this indicator; and 2) that the rating thresholds should be adjusted to set a higher bar for a "Very Good", perhaps a 10% threshold instead of the current 20% threshold used in Lake Ontario and this report.
Desired Future Status—VERY GOOD: This rating is a best guess based on the importance of shoreline processes and the potential for shoreline restoration in many areas.

Southern
Current Status—VERY GOOD: See above discussion of current status for northern Lake Huron above. If the thresholds were shifted to require less than 10% hardening for a "Very Good" rating, southern Lake Huron might drop to a "Good" rating. The NOAA data used for this assessment aren't precise enough to be certain about the actual percentage, but suggest that hardening in southern Lake Huron could be between 10% and 15%.
Desired Future Status—VERY GOOD: This rating is a best guess based on the importance of shoreline processes and the potential for shoreline restoration in many areas.

<u>Indicator: Bed load traps and groins (number of structures per length of shoreline)</u>
Description: A measure of the number of artificial shoreline structures along particular segments of the northern and southern shoreline of Lake Huron. Artificial structures, such as jetties, that project out into the lake and disrupt littoral flow patterns and sediment processes. Resulting disrupted sediment processes include trapping of sediment on the updrift side of structures resulting in sediment-starved conditions on the downdrift side (Meadows et al. 2005). There is a substantial amount of data indicating that bed load traps and groins alter shoreline processes, particularly water flow and sediment transport (Herdendorf 1973, 1987, Carter et al. 1981, Li et al. 2001, Meadows et al. 2005). Shoreline structure densities in Goforth and Carman (2005) did not discriminate between large and small structures, so further evaluation of this indicator ratings is needed in the future. This indicator is also used for the Nearshore Zone assessment.

Basis for Assessing Indicator: Published studies are generally insufficient for identifying thresholds of impacts; however, in Goforth and Carman (2005) fish assemblages appear to be severely degraded by 300 trap and groin structures per 100 km of updrift shoreline. Therefore, this break was used to delineate between FAIR and POOR. Other breaks were set incrementally and adopted from the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009), which were based on thresholds developed by the Swedish Environmental Protection Agency (2006) (Environmental Quality Criteria for Coasts).
Northern:
Current Status—GOOD: In general, experts said that most of northern Lake Huron had low densities of bed load traps and groins. This rating is based on expert opinion, but should be validated with analysis in the future.

Desired Future Status—GOOD: Maintaining an overall goal of GOOD is dependent upon maintaining significant areas of the lake that are VERY GOOD. Restoration of areas would also help to maintain a GOOD rating.

Southern:
Current Status—FAIR: In general, experts said that many areas southern Lake Huron and southern Georgian Bay have relatively high densities of shoreline perpendicular structures—mostly near urbanized areas, with some southern Lake Huron shoreline reaches with GOOD densities, but others with POOR. Rating is based on expert opinion, but should be validated with analysis in the future.
Desired Future Status—GOOD: This rating is an educated guess based upon a low likelihood of reaching VERY GOOD status. Reaching an overall goal of GOOD is dependent upon maintaining current GOOD and VERY GOOD areas and restoring other areas.

SIZE

KEA: Size / extent of characteristic communities / ecosystems

<u>Indicator: Percent natural land cover within 2 km of shoreline</u>
Description: The percentage of undeveloped land within 2 km of the shoreline in northern and southern Lake Huron. The literature indicates that alteration of natural land cover within Coastal Terrestrial Systems (ex. coastal forests or grasslands) may have a significant impact on the Nearshore Zone habitat and its inhabitants and on water quality and quantity within the watershed (SOLEC, nearshore areas of the Great Lakes 2008, Dodd and Smith 2003).

Basis for Assessing Indicator: We adopted the same indicator rankings that were used in the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009, Dodd and Smith 2003, Findlay and Lenton 2001, Rubbo and Kiesecker 2005, and Environment Canada and the Central Lake Ontario Conservation Authority).

Northern:
Current Status— GOOD: This rating is based on opinion GIS assessment that produced a measurement of 61.5%.
Desired Future Status—VERY GOOD: It is feasible, with effort, to maintain the rating of VERY GOOD into the future.

Southern:
Current Status— GOOD: This rating is based on a GIS assessment that produced a measurement of 53.7%.
Desired Future Status— GOOD: Given the constraints of the current landscape in the southern portion of the Lake Huron basin, maintaining a GOOD rating is feasible based on expert opinion.

4.3g Aerial Migrants

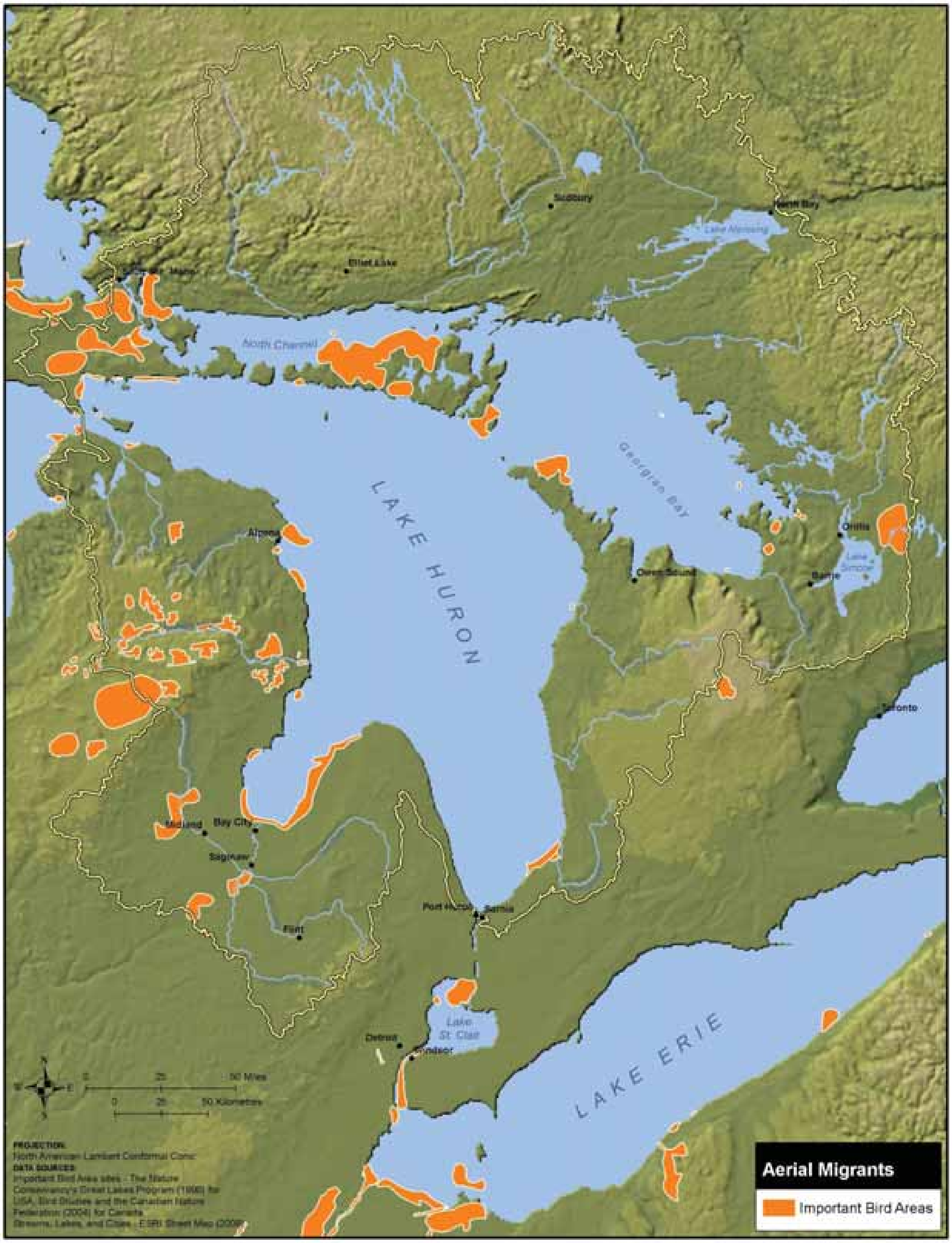

Figure 11: Map of migratory land bird stopover habitat (modeled); represents the Aerial Migrants' biodiversity feature.

This feature includes Aerial Migrants that have high fidelity to Lake Huron, and for which migratory corridors associated with the lake are crucial for their survival. This feature is represented by birds, bats, and insects. Lake Huron, western Lake Erie, and the St. Clair and Detroit Rivers an important flyway for many species of migrating birds, and the shorelines of Lake Huron provide stopover sites for millions of birds, especially landbirds. There are globally or nationally important concentrations of Red-necked Grebes in northern Lake Huron, Tundra Swans in Saginaw Bay, and landbirds along a number of shorelines and peninsulas of Lake Huron, such as Tawas Point (MI), , the tip of the Bruce Peninsula (ON), and much of the northern shore of Lake Huron in both the US and Canada. Places where migrants concentrate are important refueling sites and provide shelter for birds. The large number of Islands in Lake Huron likely provides critical refugia for landbird migrants. At least some globally rare species, such as Kirtland's Warbler and Piping Plovers migrate over Lake Huron and use the shoreline as stopover sites. Important Bird Areas for migrating birds have been identified in Canada and the United States.

Though this feature includes several taxonomic groups, the viability assessment is almost entirely limited to birds due to the preponderance of data and better understanding of bird migration relative to the other groups. Information on the distribution of bats during migration is very poorly known. Studies are badly needed to identify where and when bats migrate around Lake Huron. Similarly, the distribution of migrating insects, such as some Odonates and Monarchs, requires further investigation.

Like the Coastal Wetlands and Coastal Terrestrial Systems features, indicators for many KEAs were geographically stratified for northern and southern Lake Huron (see section 4.1 Methodology).

Nested Biodiversity Conservation Features

- all types of migratory birds
- bats
- dragonflies
- butterflies

Summary of Viability

The Aerial Migrants biodiversity feature of Lake Huron has a viability status of FAIR, overall (Table 3). Due to a lack of data on population demographics and size of these migrating animals, this rating is based only on KEAs in the landscape context category (Table 10).

Among the KEAs for this feature are *anthropogenic disturbance of habitat*, *coastal land use*, *habitat availability*, *landscape pattern and structure*, *management status*, and *size/extent of characteristic communities* (as in the other coastal features, this one is stratified by northern and southern Lake Huron). The indicator for anthropogenic disturbance is a qualitative rating of the amount of recreation on the shoreline and is currently rated as GOOD and FAIR for northern and southern Lake Huron, respectively. Coastal land use is indicated by the percentage of natural land cover 2-5 km from the lake and is VERY GOOD in the north and GOOD in the south. Habitat availability and size/extent of characteristic communities were mostly evaluated by using parameters developed to model habitat for migrating birds (Ewert et al. 2006) and shows a pattern of being rated as VERY GOOD or GOOD in northern Lake Huron and typically FAIR in southern Lake Huron, reflecting the distinct difference in land conversion between the two portions of the basin.

Table 10: KEAs and indicators for the Aerial Migrants biodiversity feature.

KEAs and Indicators for Aerial Migrants						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context	Anthropogenic disturbance of habitat	Amount of recreation and other activities on the shoreline and in water in northern Lake Huron	very high activity	high activity	***moderate activity***	low activity
	Anthropogenic disturbance of habitat	Amount of recreation and other activities on the shoreline and in water in southern Lake Huron	very high activity	***high activity***	moderate activity	low activity
	Coastal land use	percentage of area 2-5 km from lake that is in natural land cover in northern Lake Huron	<10	10 - 25	>25 - 40	***>40***
	Coastal land use	percentage of area 2-5 km from lake that is in natural land cover in southern Lake Huron	<10	10 - 25	**>25 - 40**	*>40*
	Habitat availability	Amount of habitat for migrating bats--NLH	very little	not enough	enough	***abundant***
	Habitat availability	Amount of habitat for migrating bats--SLH	very little	**not enough**	*enough*	abundant
	Habitat availability	percentage of 2 km shoreline area that scores >2 for landbirds-NLH	<10	10 - 30	**>30 - 50**	*>50*

KEAs and Indicators for Aerial Migrants						
Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context cont.	Habitat availability	percentage of 2 km shoreline area that scores >2 for landbirds--SLH	<10	**10 - 30**	*>30 - 50*	>50
	Habitat availability	percentage of 2 km shoreline area that scores >2 for shorebirds--NLH	<5	5 - 10	10 - 40	***>40***
	Habitat availability	percentage of 2 km shoreline area that scores >2 for shorebirds--SLH	<5	**5 - 10**	*10 - 40*	>40
	Habitat availability	percentage of 2 km shoreline area that scores >2 for waterfowl--NLH	<30	30 - 50	>50 - 80	***>80***
	Habitat availability	percentage of 2 km shoreline area that scores >2 for waterfowl--SLH	<30	**30 - 50**	*>50 - 80*	>80
	Landscape pattern (mosaic) & structure	Mean patch size of landbird stopover habitat with priority score >2 in northern Lake Huron	<20 ha	20 - 100 ha	>100- 200 ha	***>200 ha***
	Landscape pattern (mosaic) & structure	Mean patch size of landbird stopover habitat with priority score >2 in southern Lake Huron	<20 ha	**20 - 100 ha**	*>100 - 200 ha*	>200 ha

KEAs and Indicators for Aerial Migrants

Category	Key Attribute	Indicator	POOR	FAIR	GOOD	VERY GOOD
Landscape Context cont.	Management Status	percentage of high priority habitat (>9 total score) that is in conservation management--NLH	<50	**50 - 80**	*>80 - <100*	100
	Management Status	percentage of high priority habitat (>9 total score) that is in conservation management--SLH	<50	**50 - 80**	*>80 - <100*	100
	Size / extent of characteristic communities / ecosystems	percentage of northern Lake Huron basin that scores >2 for landbirds	<10	10 - 30	>30 - 50	***>50***
	Size / extent of characteristic communities / ecosystems	percentage of southern Lake Huron basin that scores >2 for landbirds	<10	**10 - 30**	*>30 - 50*	>50

LANDSCAPE CONTEXT

KEA: Anthropogenic disturbance of habitat

<u>Indicator: Amount of recreation and other activities on the shoreline and in water</u>

Description: Research (Helmers 1992, Pfister et al. 1992, Buger et al. 2007) has documented that human activities including walking with pets along the shoreline can disturb migrating shorebirds and waterfowl. While these studies have not been in the Great Lakes region, but it is likely that results from these studies apply to the Great Lakes shoreline. A more detailed literature review would likely allow us to be more specific in defining what is meant by activity, including the nature of the disturbance (humans, dogs, etc.), the frequency, and duration of the disturbance.

Basis for Assessing Indicator: The paucity of data on recreational activities made it impossible to develop a quantitative indicator, so this indicator is a qualitative placeholder. More research is needed.

Northern:
Current Status—GOOD: This rating is an educated guess.
Desired Future Status—GOOD: It seems reasonable to maintain the current status.

Southern:
Current Status—FAIR: This rating is an educated guess; it is assumed that recreational use is roughly correlated with human population density.
Desired Future Status—FAIR: It seems reasonable to maintain the current status.

KEA: Coastal land use

Indicator: Percentage of area 2-5 km from lake that is in natural land cover
Description: The amount of land in natural cover determines the distribution of landbirds across the landscape; literature reviews suggest that the relative abundance of birds and/or food supplies are sufficient for migrants when the landscape is >40% natural cover (D. Ewert, pers. comm.). There may be compensatory responses of migrating birds below this threshold as indicated by the quantitative values assigned to the indicator rankings.

Basis for Assessing Indicator: Based on literature review for birds although additional studies needed to develop these criteria are needed.

Northern:
Current Status—VERY GOOD: This rating is based on a GIS assessment that produced a measurement of 79.7%.
Desired Future Status—VERY GOOD: Maintaining current status should be a priority and seems feasible for this feature.

Southern:
Current Status—GOOD: This rating is based on a GIS assessment that produced a measurement of 38.1%.
Desired Future Status—VERY GOOD: It seems feasible to raise this rating to VERY GOOD.

KEA: Habitat availability

Indicator: Amount of habitat for migrating bats
Description: This indicator is included here mostly to acknowledge that habitat may be a limiting factor for bats migrating to seasonal habitats.

Basis for Assessing Indicator: These rating thresholds are qualitative placeholders. More research is needed.

Northern:
Current Status—VERY GOOD: Experts agreed that bat habitat probably corresponds well with natural land cover, though there are likely specific parts of the landscape that are more important than others (e.g.,

riparian forests). This rating reflects the relatively intact character of northern Lake Huron and corresponds to the land cover ratings developed for other.
Desired Future Status—VERY GOOD: The goal should be to maintain what is assumed to be very good habitat for migrating bats. In support of this goal, there is a need to improve our understanding of habitat preferences for migrating bats.

Southern:
Current Status—FAIR: Natural land cover in southern Lake Huron is much less extensive than in northern Lake Huron. There may be enough habitat in key areas, such as shoreline and riparian forests, so that habitat is not limiting to migrating bats. One potential factor which may reduce habitat availability is construction of wind turbines. At some sites, large numbers of bats are killed and, given their low reproductive potential, any additional mortality may be a serious threat. Wind turbines are most likely to be near Lake Huron or in open agricultural landscapes and thus in the southern part of Lake Huron landscape.
Desired Future Status—GOOD: This rating is based on expert opinion.

Indicator: Percentage of shoreline area within 2 km that scores >2 for landbirds

Description: Based on models developed in western Lake Erie and applied to Lake Huron, the amount of area that scores above 2 (on a scale of 1-5) for landbirds in the most important area—within 2 km of the shoreline.

Basis for Assessing Indicator: The rationale is based on both literature and expert opinion, as described more fully in a report on modeling of stopover habitat in the western Lake Erie basin (Ewert et al. 2006). Experts identified the most important attributes of stopover habitat for landbirds and raptors, shorebirds, and waterfowl, and used a GIS analysis to map stopover habitat values across the basin.

Northern:
Current Status—GOOD: This rating is based on a GIS assessment that produced a measurement of 38.6%.
Desired Future Status—VERY GOOD: It seems feasible for the VERY GOOD rating to be achieved.

Southern:
Current Status—FAIR: This rating is based on a GIS assessment that produced a measurement of 28.5%.
Desired Future Status—GOOD: This rating seems feasible as it would require a relatively modest increase in available habitat.

Indicator: Percentage of shoreline area within 2 km that scores >2 for shorebirds

Description: Based on models developed in western Lake Erie and applied to Lake Huron, the amount of area that scores above 2 (on a scale of 1-5) for shorebirds in the most important area—within 2 km of the shoreline. This indicator reflects the importance of shoreline stopover habitat to shorebirds.

Basis for Assessing Indicator: The rationale is based on both literature and expert opinion, as described more fully in a report on modeling of stopover habitat in the western Lake Erie basin (Ewert et al. 2006). Experts identified the most important attributes of stopover habitat for landbirds and raptors, shorebirds, and waterfowl, and used a GIS analysis to map stopover habitat values across the basin.

Northern:
Current Status—VERY GOOD: This rating is based on expert opinion.
Desired Future Status—VERY GOOD: This rating is based on expert opinion, but maintenance of rating seems feasible.

Southern:
Current Status—FAIR: This rating is based on expert opinion.
Desired Future Status—GOOD: This rating is based on expert opinion.

Indicator: Percentage of shoreline area within 2 km that scores >2 for waterfowl
Description: Based on models developed in western Lake Erie and applied to Lake Huron, the amount of area that scores above 2 (on a scale of 1-5) for landbirds in the most important area—within 2 km of the shoreline. This indicator reflects the importance of Coastal Wetlands and open water to migrating waterfowl.

Basis for Assessing Indicator: The rationale is based on both literature and expert opinion, as described more fully in a report on modeling of stopover habitat in the western Lake Erie basin (Ewert et al. 2006). Experts identified the most important attributes of stopover habitat for landbirds and raptors, shorebirds, and waterfowl, and used a GIS analysis to map stopover habitat values across the basin.

Northern:
Current Status—VERY GOOD: This rating is based on expert opinion.
Desired Future Status—VERY GOOD: This rating is based on expert opinion.

Southern:
Current Status—FAIR: This rating is based on expert opinion; ongoing modeling efforts will refine this rating.
Desired Future Status—GOOD: Rating seems feasible but should be refined after ongoing modeling efforts are completed.

KEA: Landscape pattern (mosaic) & structure

Indicator: Mean patch size of landbird stopover habitat with priority score >2
Description: Habitat modeling for migrating birds, based on work done in Lake Erie, has been completed for Lake Huron, and patch size is being calculated for each part of the Lake Huron basin. Though some studies have addressed the importance of patch size as a determinant of stopover habitat use by migrating landbirds (Williams 2002), the issue is still unresolved (Dave Ewert, pers. comm.).

Basis for Assessing Indicator: The patch size criteria described here are very crude; there are few supporting studies to indicate if patch size significantly affects survivorship during migration. If larger patches offer more or a wider array of food resources then larger patches might offer migrating landbirds more conservation value than small patches. However, there is an interaction between patch size and proportion of landscape in natural cover – generally larger patch sizes are associated with more intact landscapes. Our indicators reflect this relationship.

Northern:
Current Status—VERY GOOD: This rating is based on a GIS assessment of stopover habitat.
Desired Future Status—VERY GOOD: Maintaining the current quality of stopover habitat is a reasonable goal for northern Lake Huron.

Southern:
Current Status—FAIR: This rating is based on a GIS assessment of stopover habitat.
Desired Future Status—GOOD: It may or may not be reasonable to expect to raise this rating to GOOD. Rating should be reviewed after ongoing modeling efforts are completed.

KEA: Management status

<u>Indicator: Percentage of high priority habitat (>9 total score) that is in conservation management</u>
Description: This indicator reflects whether the best habitat for Aerial Migrants is sufficiently protected and managed for biodiversity. It reflects both landscape features and site features which can be described with GIS. Consequently, this score is a first iteration on how to measure our success in defining what we believe drives the distribution of migrants. While overall habitat for migrants may or may not be limiting, depending on geographic location, the best quality habitats (serving multiple groups of migrants) may be limiting over much of the Lake Huron basin and should be conserved.

Basis for Assessing Indicator: This indicator and thresholds are based on both literature and expert opinion, as described more fully in a report on modeling of stopover habitat in the western Lake Erie basin (Ewert et al. 2006). Experts identified the most important attributes of stopover habitat for landbirds and raptors, shorebirds, and waterfowl, and used a GIS analysis to map stopover habitat values across the basin. The criteria used to define the proportion of habitat that is in high priority conservation management is arbitrary. Limiting factors on migratory birds, especially landbirds, are poorly known. The criteria noted here reflect potential benchmarks only.

Northern:
Current Status—FAIR: This rating is based on a rapid assessment of the overlap between Conservation and Recreation Lands and high priority migratory bird habitat along the shore of Alpena, Presque Isle, and Cheboygan counties in Michigan. A more rigorous GIS analysis should be performed to validate this rating for northern Lake Huron.
Desired Future Status—GOOD: It is highly unlikely that a rating of VERY GOOD (100% conserved) can be achieved, so a GOOD rating seems a reasonable goal.

Southern:
Current Status—FAIR: This rating is based on a rapid assessment of the overlap between Conservation and Recreation Lands and high priority migratory bird habitat in Saginaw Bay. A more rigorous GIS analysis should be performed to validate this rating for southern Lake Huron.
Desired Future Status—GOOD: See description for northern Lake Huron above.

KEA: Size / extent of characteristic communities / ecosystems

Indicator: Percentage of the basin that scores >2 for landbirds
Description: This indicator employs habitat models based on work in western Lake Erie and recently completed for Lake Huron. The survival of landbirds moving over land in the Lake Huron basin may be limited in areas that lack a suitable amount of stopover habitat (Dave Ewert, pers. comm.). This indicator reflects landscape considerations for landbirds.

Basis for Assessing Indicator: This indicator and thresholds are based on both literature and expert opinion, as described more fully in a report on modeling of stopover habitat in the western Lake Erie basin (Ewert et al. 2006). Experts identified the most important attributes of stopover habitat for landbirds and raptors, shorebirds, and waterfowl, and used a GIS analysis to map stopover habitat values across the basin. Relatively low ranked sites will shelter migrants under a wide range of conditions and hence there is a need to have a network of stopover sites scattered across the landscape including those with relatively low ranks.

Northern:
Current Status—VERY GOOD: The relatively intact land cover in northern Lake Huron provides adequate stopover habitat.
Desired Future Status—VERY GOOD: Maintaining this amount of habitat is a reasonable goal.

Southern:
Current Status—FAIR: Natural land cover is not very intact in the southern portion of Lake Huron. This rating is based on expert opinion.
Desired Future Status—GOOD: Increasing the current status to a good seems reasonable based on expert opinion.

5. THREATS ASSESSMENT

Significant anthropogenic changes began more than 150 years ago and continue today as the Lake Huron basin has been converted to agricultural, urban, and recreational uses to meet the needs of its growing population. Much of the Lake Huron Basin has been altered or impacted in some form by these activities, which have both direct and indirect impacts to biodiversity. These resulted in direct habitat loss due to development; a loss of connectivity between the lake and tributaries; alteration in the chemical, physical and biological structure of the Nearshore Zone and coastal environments; inputs of non-point source pollution to the freshwater ecosystem; and the far-reaching effects of non-native invasive species on the trophic dynamics of the lake. In addition to these stressors, climate change is projected to further exacerbate these effects and impact the ecosystem through hydrologic and temperature changes.

5.1 Methodology

The CAP process relies on identifying and developing strategies to abate the most serious threats to biodiversity features. The identification of critical threats began at Workshop I, and continued in small working groups to finalize results. The purpose of this exercise was to identify and rank direct threats to Lake Huron's biodiversity features to determine which were most critical to the viability of these features. In many cases, a threat may be quite severe in some regions, whereas in other regions it may be insignificant. Where possible, this regional heterogeneity was captured; however, summary rankings reflect a single score for each threat at the basin-wide scale.

Workshop I participants assessed threats in terms of their ***scope***, ***severity***, and ***irreversibility*** on each of the biodiversity features and these were then rated using Miradi computer software (https//miradi.org) which uses an algorithm to calculate each threat's overall rank within and among biodiversity features. The ranking criteria (TNC 2007) are as follows:

Scope: Most commonly defined spatially as the proportion of the biodiversity feature that can be reasonably expected to be affected by the threat within 10 years (e.g., given the continuation of current circumstances and trends.

Severity: The level of damage to the feature from the threat that can reasonably be expected given the continuation of current circumstances and trends.

Irreversibility: The degree to which the effects of a threat can be reversed and the biodiversity feature can be restored.

Scope:

Very High: The threat is likely to be pervasive in its scope, affecting the feature across all or most (71-100%) of its occurrence/population.
High: The threat is likely to be widespread in its scope, affecting the feature across much (31-70%) of its occurrence/population.
Medium: The threat is likely to be restricted in its scope, affecting the feature across some (11-30%) of its occurrence/population.
Low: The threat is likely to be very narrow in its scope, affecting the feature across a small proportion (1-10%) of its occurrence/population.

Severity:

Very High: Within the scope, the threat is likely to destroy or eliminate the feature, or reduce its population by 71-100% within 10 years or three generations.
High: Within the scope, the threat is likely to seriously degrade/reduce the feature or reduce its population by 31-70% within 10 years or three generations.
Medium: Within the scope, the threat is likely to moderately degrade/reduce the feature or reduce its population by 11-30% within 10 years or three generations.

Low: Within the scope, the threat is likely to only slightly degrade/reduce the feature or reduce its population by 1-10% within 10 years or three generations.

Irreversibility:
Very High: The effects of the threat cannot be reversed and it is very unlikely the feature can be restored, and/or it would take more than 100 years to achieve this (e.g., wetlands converted to a shopping center).
High: The effects of the threat can technically be reversed and the feature restored, but it is not practically affordable and/or it would take 21-100 years to achieve this (e.g., wetland converted to agriculture).
Medium: The effects of the threat can be reversed and the feature restored with a reasonable commitment of resources and/or within 6-20 years (e.g., ditching and draining of wetland).
Low: The effects of the threat are easily reversible and the feature can be easily restored at a relatively low cost and/or within 0-5 years (e.g., off-road vehicles trespassing in wetland).

5.1a Understanding Threats and Transitioning to Strategies

Threats that received a basin-wide rank of Very High or High were considered the most critical threats to focus on for the subsequent steps in the Conservation Action Plan process. For efficiency, some threats were combined when the contributing factors and likely strategies were considered similar or complementary. At Workshop II, participants formed break-out groups to develop a conceptual model for each threat. Conceptual models are tools that visually depict our understanding of a system or situation by explicitly documenting the threats to biodiversity features, detailing major factors that lead to or perpetuate each critical threat, and defining the causal relationships among those factors (Figure 12 and 13). This tool can help identify factors that may represent opportunities for threat abatement. Participants self-selected into the threat-based working groups to discuss the biological, political, economic, and socio-cultural context of the contributing factors that drive direct threats and hence impact biodiversity features.

Working group participants used post-it notes, flip charts, index cards, and interactive wall charts to facilitate the conceptual modeling exercise (Figure 12). Stressors were identified to elucidate how each direct threat impacts the biodiversity features (threats may affect more than one feature). Indirect threats and other important contributing factors that positively or negatively influence direct threats were then identified and integrated into the conceptual model. Most working groups also developed a list of stresses that detailed how direct threat impacts biodiversity features. These drivers of direct threats and models served as the entry point to discuss potential opportunities to develop conservation interventions.

Figure 12: One of the conceptual models developed at Workshop II.

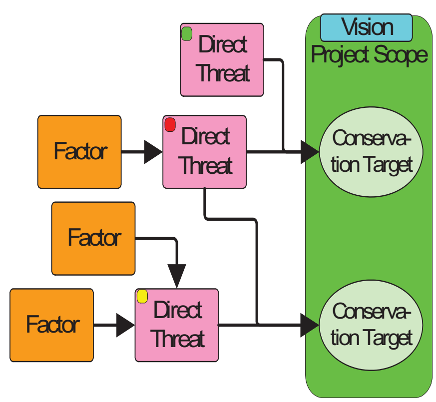

Figure 13: Example of conceptual model in Miradi.

5.2 Critical Threats

Significant challenges in completing an assessment and prioritization of threats were the large scale of the Lake Huron basin, its ecological complexity, and differences in land use, geology, and population density across the Lake Huron basin. Of particular concern to workshop participants were differences between the more rural and remote northern portion of Lake Huron and its more populated and intensely used southern region. While each threat presented in the matrix (

Table 11) represents a stress to one or more biodiversity features; threat ranking averaged across the Lake Huron basin resulted in five threats being identified as the most critical to Lake Huron's biodiversity:

1. Invasive non-native aquatic and terrestrial species;
2. Housing and urban development and shoreline alterations;
3. Climate change;
4. Dams and other barriers; and
5. Agricultural, forestry and urban non-point source pollution.

Note that these five threats represent seven of the threats listed in Table 11. For efficiency, non-native invasive aquatic and terrestrial species were addressed together and shoreline alteration was also addressed with housing and urban development. These most severe threats are consistent with the findings of several important papers, reports, and action plans written in recent years.

In 1996, SOLEC commissioned background papers about Nearshore Zone ecosystems. Edsall and Charlton (1997) commented that among the most destructive human activities for the Nearshore Zone waters has been the introduction of non-native invasive species. Documented invasions of non-native aquatic species increased from 166 to 184 between 1996 and 2008. Mackey (2009) noted the single most important anthropogenic factor disrupting nearshore-coastal processes and pathways is increasing shoreline development and the physical alteration of the land-water interface. Great Lakes coastal wetland community modeling indicates that projected low water levels under most climate change scenarios will have a significant impact on the distribution and abundance of wetland vegetation, bird, and fish communities (Mortsch et al. 2006). Urban sprawl and poor land-use practices that lead to non-point source pollution, draining wetlands for agriculture, and urbanization are recognized as causal factors of loss of habitat condition and connectivity between open-lake waters with wetlands, tributaries, and Nearshore Zones that are used as fish spawning and nursery habitats. Dams and other barriers are responsible for at least 86% of major tributary habitats being disconnected from the lake (Roseman et al. 2009). The Great Lakes Fishery Commission's Environmental Objectives for Lake Huron (Liskauskas et al. 2007) also substantiate these critical threats as determinants of functional fish habitats, shoreline processes, food web structure, and water quality. Northern and eastern Georgian Bay regions are identified as having a high level of threat to island biodiversity due to housing and cottage development (Henson et al. 2010). Incremental loss of coastal and inland wetlands, through wetland drainage and filling to support urban development has resulted in significant habitat loss and non-point source pollution in portions of the basin (Liskauskas et al. 2007, Lake Huron Binational Partnership. 2008). The spread of non-native, invasive plant species such as phragmites (*Phragmites australis australis)*, reed canary grass (*Phalaris arundinacea*), and purple loosestrife (*Lythrum salicaria*) outcompete native plant species and reduce habitat quality and quantity for waterbirds (Zeran et al. 2009). The above mentioned threats are also noted concerns to wildlife managers (Eagle et al. 2005).

Table 11: Ranking of threats to Lake Huron biodiversity features. Threats were ranked for each feature, if applicable to that feature, with separate rankings (Low, Medium, High, Very High) for scope, severity, and landscape context.

THREATS	Aerial Migrants	Coastal terrestrial	Coastal wetlands	Islands	Native migratory fish	Nearshore	Offshore	Summary Threat Rating
Invasive Non-Native Aquatic Species	H L V Medium	L L L Low	V H V Very High		V M H Medium	V H V Very High	V V V Very High	Very High
Housing & Urban Development	H H V Very High	H H V Very High	H V V Very High	M V V High		H H V Very High		Very High
Climate change	V M V High	V H V Very High	V M V High	V M V High	V M H Medium	V M V High	V M V High	Very High
Invasive non-native terrestrial species		H H H High	V H H High	V M H Medium				High
Dams & Other Barriers			L H H Low		H V H High	H H M High		High
Agricultural, Forestry and Urban Non Point Runoff		L M M Low	H H H High		M M M Medium	H H H High	V L H Low	High
Urban, Industrial and Agricultural Point		L H V Medium	M L H Low		M M M Medium	L H H Low	V L H Low	Medium
Shoreline Alterations	L L H Low	M M M Medium	M H H Medium	L M H Low		M M M Medium		Medium
Renewable & Non-renewable Energy	M M H Medium	L H V Medium	L L L Low	L M H Low	L L M Low	L M M Low		Medium
Navigation & Recreational Dredging & Blasting			M M H Medium		L M H Low	M M H Medium	L L L Low	Medium
Mining & Quarrying		L V V Medium	L L H Low	L V V Medium		L L H Low		Medium
Incompatible resource management		H M M Medium	L M M Low	L H H Low	V M H Medium	M M M Medium	V H M High	Medium
Airborne pollutants		M M M Medium	V M V High		V L M Low	V L V Medium	V L H Low	Medium
Recreational activities	L L L Low	M M M Medium	L M L Low					Low
Contaminated Sediments			L M H Low		L H H Low	L M H Low	V L V Medium	Low
Agricultural conversion	M L L Low	L H H Low	L H H Low					Low
Summary Target Rating	High	Very High	Very High	High	High	Very High	High	Very High

5.2a Invasive Non-Native Aquatic and Terrestrial Species

Why Are Invasive Species a High-Ranking Critical Threat?

This threat includes aquatic and terrestrial species that are invasive and not native to Lake Huron. Invasive species threaten the diversity, abundance, and long-term viability of native species and the ecological stability of Lake Huron. The introduction of invasive species into the Lake Huron ecosystem has altered or disrupted existing relationships and ecological processes (LHBP 2008; Roseman et al. 2009). Invasive species generally have life history traits that include rapid growth, early sexual maturity (producing new generations quickly), and ability to spread rapidly; usually with multiple mechanisms for dispersing and often linked to human activity and disturbance. These species tend to be abundant and widely distributed in their original ranges, are competitively hardy, tolerating a range of conditions or habitats (making them opportunists), and often prey on a variety of species (Ricciardi and Rasmussen 1998). Invasive species also generally benefit from a lack of natural predators or parasites in introduced locations (Lake and Leishman 2004). These characteristics give them a competitive advantage for food and habitat over native species, which may be attuned to very specific needs that can be met in only certain portions of the Lake Huron basin.

Aquatic invasive species currently established and of management concern include truly aquatic species such as sea lamprey (*Petromyzon marinus*), zebra and quagga mussels (*Dreissena spp.*), round and tubenose gobies (*Neogobius spp.*), ruffe (*Gymnocephalus cernuus)*, spiny water flea (*Bythotrephes longimanus*) as well as wetland plant species, including Eurasian water milfoil (*Myriophyllum spicatum*), purple loosestrife, and phragmites (LHBP 2008). Terrestrial invasive species, besides the wetland species listed above, that are currently established and of management concern include spotted knapweed (*Centaurea maculosa* Lam), common buckthorn (*Rhamnus cathartica*), sweet clover (*Melilotus alba*), soapwort (*Saponaria officinalis*), ox-eye daisy (*Chrysanthemum leucanthemum*), lawn prunella (*Prunella vulgaris*), Canada bluegrass (*Poa compressa*), common St. John's-wort (*Hypericum perforatum*), and emerald ash borer (*Agrilus planipennis Fairmair*). Invasive species are expected to continue to enter the Great Lakes (Ricciardi 2006), therefore, additional attention was directed toward species with a high risk for future introduction. Some of these high risk species have been identified, such as hydrilla (*Hydrilla verticillata*), or Asian bighead (*Hypophthalmichthys nobilis*) or silver carp (*Hypophthalmichthys molitrix*) (International Joint Commission 2009, U.S. EPA 2008). High-risk aquatic species that have not yet established in the U.S. and Canada have also been identified (Kolar and Lodge 2002). However, there is also concern about unknown species that may pose threats, establishing a need for risk assessment and monitoring processes and protocols for early detection (IJC 2009). These invasive species are not intended to be an exhaustive list, but rather a sampling of high profile species used as examples in discussing invasive species threats and strategy development for Lake Huron.[3]

Understanding the origin of invasive species, mechanisms of introduction, and degree of ecological impacts is complex. The diversity of invasive species affecting Great Lakes and specifically Lake Huron run the range of fish, invertebrates, plants, algae, and pathogens. Introduction of these organisms reflects a worldwide problem. Species have been transported to the Great Lakes from Europe, Asia, Atlantic Ocean, Pacific Ocean, and other regions of North America (e.g. Southern U.S. and Mississippi drainage basin); in some cases, exotic species have unknown origins. Vectors and causal pathways leading to aquatic introductions are as diverse as their originations, including waterway migration, aquaculture escape, intentional and unintentional release, recreational boating and fishing activities (e.g., bait bucket release, bilge pumps), ballast water discharge, interstate movement by railroad/highway, and a combination of known and unknown vectors (Mills et al. 1993).

Invasive species can have significant physical, chemical, and biological effects on Lake Huron waters and along the shorelines, disrupting ecosystem and food web functions. Once established, it is extremely costly to manage and remediate their impacts (IJC 2009). Eradication is rare, and experts involved in this process characterized the respective impacts of established invasive species population as largely irreversible. Sea lamprey provide a case-in-point, where control efforts do result in suppression and beneficial management

[3] For an exhaustive list, search for Lake Huron drainage on the GLANSIS database at http://www.glerl.noaa.gov/res/Programs/ncrais/nas_database.html.

results. However, these require a permanent and costly investment and if management activities were curtailed, sea lamprey populations would quickly rebound resulting in significant, negative fishery impacts (Bence and Mohr 2008).

Each new invasive species creates new instabilities in the ecosystem, decoupling predator-prey relationships, affecting food and habitat abundance and availability, and resulting in direct mortality for some native species. Each introduction creates new uncertainties regarding their short- and long-term ecological and economic impacts. Invasive species currently found in Lake Huron already reflect these significant ecosystem changes and create equally challenging ecological and economic uncertainties (Roseman et al. 2009). This threat is exemplified by Dreissenids. Introduced in the late 1980s, ecological impacts of Dreissenids are still being realized today. They restructure lower food web energy flow, creating major shifts and changes to Lake Huron's fishery (LHBP 2008, IJC 2009, U.S. EPA 2008), including fundamental changes in nutrient exchange between Nearshore Zone and Open Water Ecosystem features (Hecky et al. 2004). These changes create increased uncertainty for resource managers, and have economic impacts for coastal communities dependent on Lake Huron's diverse fisheries.

Affected Features

Aquatic and terrestrial invasive species negatively impact all biodiversity features (Table 12; LHBP 2008). For **Nearshore Zone** and **Open Water Ecosystem** features, invasive species impacts include physical changes in habitat (e.g., changes in invasive coastal wetland plants as spawning or rearing habitat, zebra mussel shells changing the character spawning reef substrate), changes in water chemistry (e.g., nutrient cycling), and food web disruptions. These changes result in uncertainties for future fisheries management activities and have implications for native species restoration. Impacts to **Coastal Wetlands** and **Coastal Terrestrial Systems** features are largely habitat alterations, especially where invasive plants may compete with, crowd out, and displace native plant community assemblages, but also include food web changes and changes in soil and water chemistry. Coastal habitat changes and food web disruptions caused by invasive species have profound implications for **Native Migratory Fish** and **Aerial Migrants** reliant on these coastal habitats for critical – and vulnerable – life-history stages for resident and migratory species, including spawning and juvenile nursery habitat for fish and nesting and stopover habitats for birds. Finally, similar to coastal habitats, **Islands** often have unique plant communities and assemblages that are compromised by the threat of invasive species.

Table 12: Threat assessment of invasive, non-native aquatic and terrestrial species to Lake Huron biodiversity features. Threats were ranked for each feature, when applicable, with separate rankings for scope, severity, and landscape context.

	Aerial Migrants		Coastal terrestrial		Coastal wetlands		Islands		Native Migratory Fish		Nearshore Zone		Open Water Ecosystem		Summary threat rating
Invasive Non-Native Aquatic Species	H L V	Medium	L L L	Low	V H V	Very High			V M H	Medium	V H V	Very High	V V V	Very High	Very High
Invasive Non-Native Terrestrial Species			H H H	High	V H H	High	V M H	Medium							High

Invasive Species Conceptual Model

A conceptual model depicting causative linkages, contributing factors, opportunities, and associated strategies for invasive species is shown in Figure 14. The conceptual model describes specific threats posed by invasive species and is organized into four themes, namely:

- Policies and practices
- Prevention of new introductions
- Management and mitigation of existing, established species
- Education and knowledge

Policies and Practices

A major concern is that policies regarding invasive species prevention are largely beyond the control of the Lake Huron basin alone, limiting the region's ability to address what are in many cases global economic forces. Invasive species are a Great Lakes basin, national, and international issue. Introduction and spread of invasive species from waterways surrounding Lake Huron – such as inland waters, other Great Lakes and the Mississippi drainage basin – increases the likelihood of Lake Huron introductions.

Invasive species introductions, issues, and management are often directly and indirectly linked to the following: 1) citizen and consumer demands for products, and land use activities of individual citizens; 2) businesses and industry responding to these demands through marketing, transport, and sales of goods; and 3) interstate and international trade occurring as a result of these consumer demands and industry responses. A need and limiting factor in preventing new and managing existing invasive species is political will, financial and human resources, and ability to coordinate and integrate regulatory activities, resource management decisions, and research and education efforts. Opportunities exist to address invasive species introductions through development of policies and regulations specific to industries and trade.

Prevention of New Introductions

Preventing new introductions is economically and ecologically preferable to managing species after they have been introduced to Lake Huron. The conceptual model identifies a challenge in that the suite of vectors and pathways of introduction for new species (and spread of species once they get here) are both diverse and many. While some vectors differ for aquatic and terrestrial species, in some cases their pathways overlap, such as with nurseries that might rear and sell both terrestrial and aquatic plants. This challenge is exacerbated by the multiple audiences (decision-makers, industries and end-users) that are linked to the decisions and demands that accompany each vector and pathway. For example, the regulatory processes and end consumers linked with the pet trade industry may differ greatly from regulatory process and end consumers of the bait industry. To further complicate an already complex threat, a new species may arrive at any time through unknown and unanticipated vectors and pathways, making prevention a daunting task. While much education and policy exists to deal with preventing introduction of new invasive species, introductions of invasive species continue to occur at an alarming rate; it is estimated that aquatic invasive species continue to arrive in the Great Lakes at a rate of one every eight months (Great Lakes Regional Collaboration (GLRC) 2005).

Successfully stemming new introductions is stymied by a lack of risk assessments, inadequate and ineffective prevention measures at known control points, and insufficient resources to engage in early detection and rapid responses to species before they become established in Lake Huron.

Management and Mitigation of Existing, Established Species

Eradication of established invasive species is not typically a realistic or feasible option. This area of the conceptual model deals primarily with preventing intra-basin movement of established species to new areas, increasing effectiveness of current control efforts where management tools and programs exist, research and development of new tools and strategies for dealing with established invasive species, and mitigating impacts to native biodiversity.

Invasive species, once introduced, often have multiple dispersal mechanisms, some natural (e.g. winds, currents, wildlife) and others linked with human activities. The conceptual model focuses on preventing movement and spread where human activities contribute to range expansion of invasive species, including recreation (boating, fishing, or trail hiking), industry and trade, and movement of forest products (including firewood). Human-induced land disturbances allowing invasive species to move into newly created open areas, such as beach or shoreline management activities, must also be addressed to minimize opportunities for invasive species colonization.

Education: A Limiting Factor and Overarching Need

Education and outreach related to invasive species was a common theme throughout the conceptual model, ranging from raising awareness of policy and regulatory decision-makers to industry representatives to individual consumers and citizens. This element of the conceptual model deals with generating awareness of risks and ecological and economic impacts of invasive introductions, and empowering audiences to access and act with resources and tools, programs and options appropriate to each stakeholder sector.

In many cases, significant educational and outreach partners, programs, and resources already exist. For example, the Great Lakes Sea Grant Program and the Ontario Invasive Species Awareness Program provide aquatic invasive species information and educational programming with a wide variety of stakeholders including policy-makers, industries, recreational stakeholders, coastal landowners, and educators.

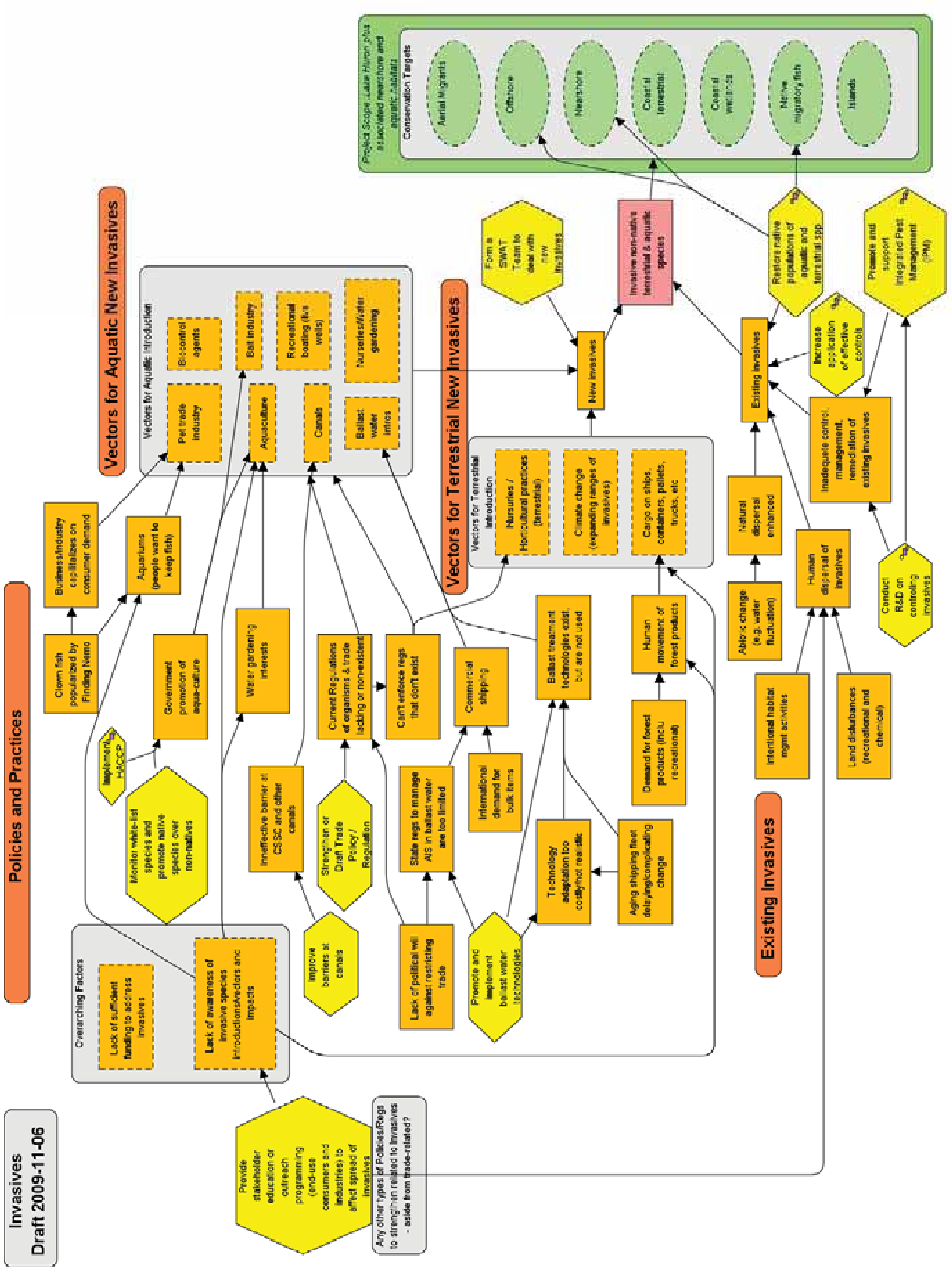

Figure 14: Conceptual model for the threat of invasive species.

5.2b Housing and Urban Development and Shoreline Alteration

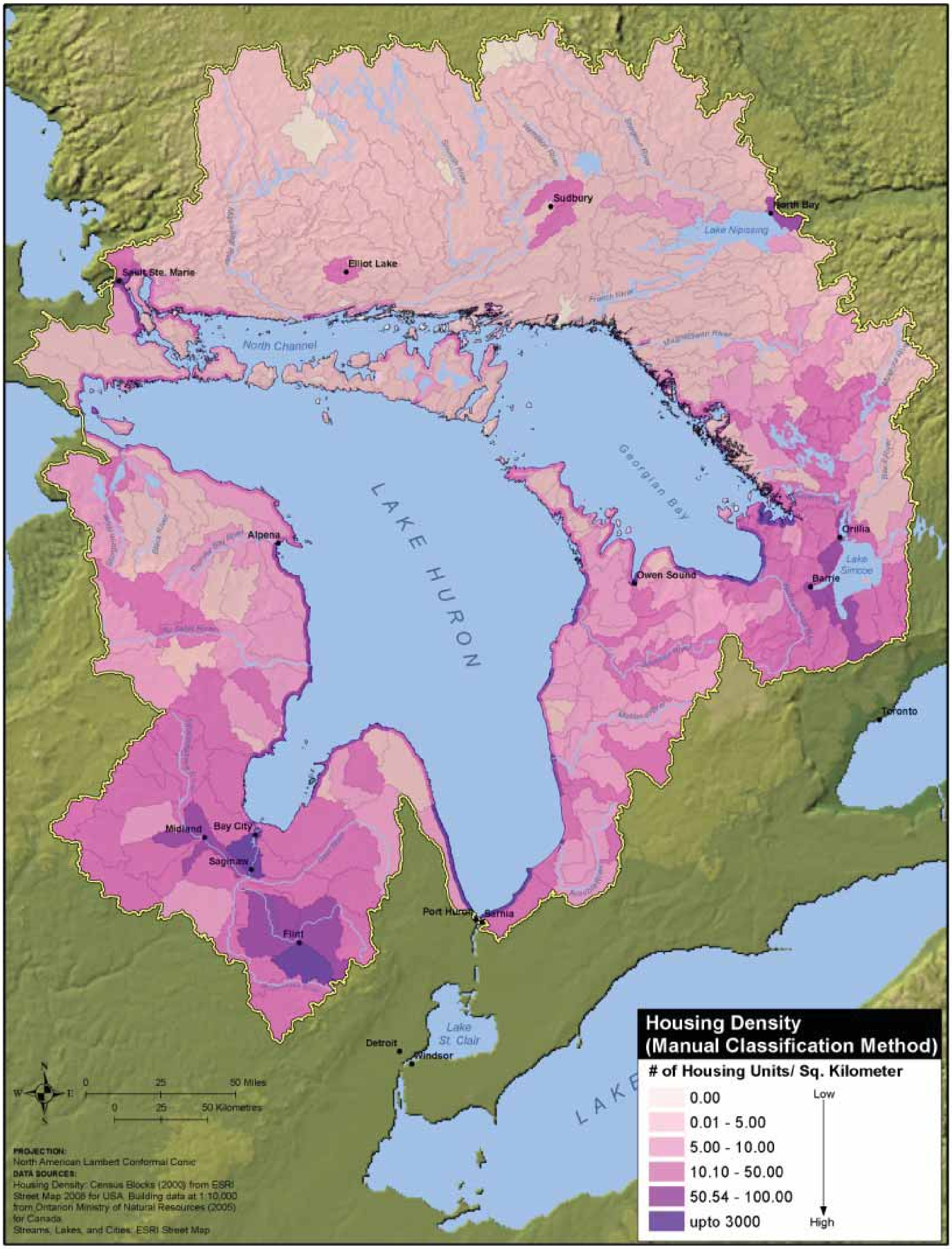

Figure 15: Housing density for the Lake Huron basin.

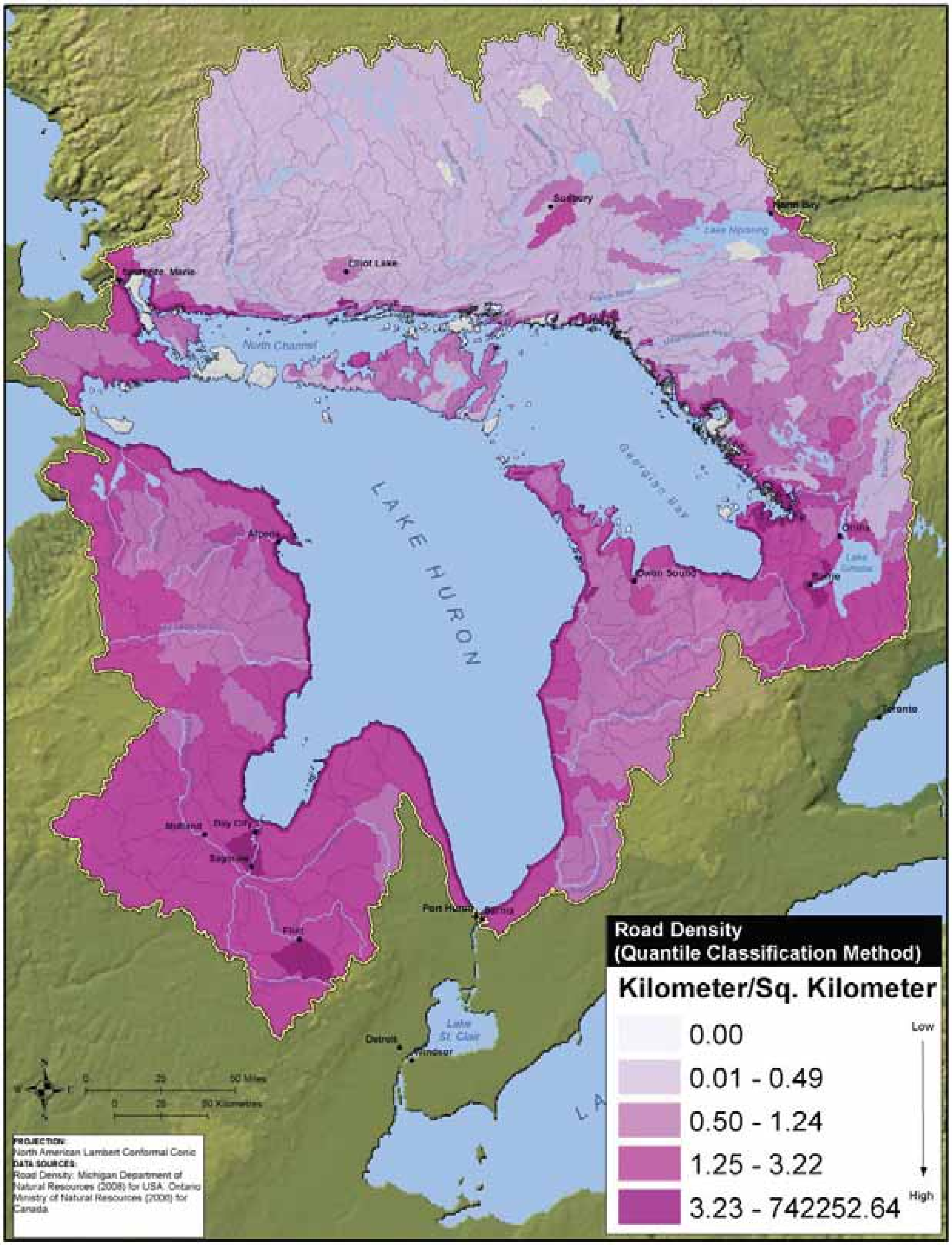

Figure 16: Road density for the Lake Huron basin.

Figure 17: Degree of artificial hardening of the Lake Huron shoreline.

Why Are Housing, Urban Development, and Shoreline Alterations High-Ranking Critical Threats?

Urban development and shoreline alterations directly degrade and destroy habitat, as well as disrupt natural forces acting on the lakebed and shoreline, flow and littoral circulatory patterns, nutrient cycles, sediment transport, and other coastal processes and pathways. Thus, the single most important anthropogenic factor impacting Nearshore Zone and the coastal zone is incompatible shoreline development and the resulting physical alteration of the land-water interface (Figures 15, 16, 17; SOLEC 2008). These physical processes create and maintain the structure and function of Coastal Wetland, coastal margin, Nearshore Zone and Island habitat and drive many species assemblages (Scheuerell and Schindler 2004), including fish populations and richness (Brazner1997).

Development also increases surface runoff (another critical threat) and reduces groundwater recharge due to "hardening" of the landscape. Lake bed modifications due to jetties, groins, and shoreline armoring not only disrupt important sustaining physical processes, they may facilitate invasions of nearshore aquatic invasive species. Chemical contaminants, nutrients, and fine-grained sediments have adversely affected Nearshore Zone habitat structure and ecosystem function (SOLEC 2008). Wetland loss and degradation continues, but since coastal wetland quality and quantity are not consistently monitored, impacts to fish and wildlife are difficult to calculate. Vehicular traffic continues to impact and alter shorelines environments by compacting sand at beach settings and disturbing habitat and wildlife. Cottage development is also associated with dune removal or alteration due to cottage development and parking. Rural development, trailer parks, and cottages construction have degraded alvars.

Affected Features

The threat of housing and urban development was rated very high in its potential impact to Aerial Migrants, Coastal Terrestrial Systems, Coastal Wetlands, and the Nearshore Zone (indeed, this threat was deemed the most significant for the Nearshore Zone biodiversity feature). This is due in large part because there is very little undeveloped shoreline left in areas of high recreation value. Residential development is most dense in the southern portions of the basin and southern Georgian Bay where cottages and year-round homes crowd the coast (Figure 15) and where road densities are generally high (Figure 16). But many other northern shoreline areas are at risk of additional shoreline development. Of particular concern are the continued loss, fragmentation, and potential degradation to the high quality and sensitive Coastal Wetlands of eastern and southern Georgian Bay, and continued stress to Coastal Wetlands of Saginaw Bay. Coastal Wetlands and Coastal Terrestrial Systems habitats offer critical refugia and stop-over sites for migratory birds (Bonter et al. 2008), as well as other Aerial Migrants. Migratory birds are most susceptible when the environmental impacts of development occur in areas with high concentrations of Aerial Migrants (Gauthreaux and Belser 1998). There is also a general loss of breeding and staging areas due to encroachment on wetlands and the Nearshore Zone and Coastal Wetland habitat has been fragmented or lost. Overall, Islands were deemed to be highly threatened by housing and urban development, with residential development being of greater general concern. The Islands of eastern Georgian Bay situated north of Severn Sound experience moderate to high development pressures. Manitoulin Island is by far the most threatened island; despite having a relatively low building density, it has significant areas of residential development, water access points, quarry development, and documented invasive aquatic species (Hensen et al. 2009).

Development is likely to seriously degrade these biodiversity features given the continued population increase and the desire to develop coastal areas. For instance, the population in eastern Georgian Bay has increased by 86% between 1981 and 2006 (Statistics Canada 2007). Across all features, it is unlikely that the effects of such development can be reversed and the biodiversity features restored to their natural condition once development has occurred (e.g., wetlands drained, filled and converted to a tourist resort). Native Migratory Fish and Open Water Ecosystem biodiversity features were considered to suffer minimal direct impacts due to this threat (Table 13).

The threat of shoreline alterations was evaluated separately from coastal development. For Aerial Migrants and Islands, it was considered low because the scope of alterations is likely to be very narrow, affecting aerial migrant and island habitat across a small proportion (1-10%) of their occurrence. Shoreline alteration is likely to only slightly directly degrade or reduce habitat for these features (by 1-10%) within ten years. While the effects could potentially be reversed and the feature restored, this is not practically affordable and/or it would take many years to achieve.

In contrast, the threat of shoreline alterations to coastal wetland, terrestrial and Nearshore Zone features is medium. While shoreline alterations are likely to negatively impact Coastal Wetlands across 11-30% of their occurrence, there is the potential that alterations will moderately to seriously degrade or reduce these features within their scope. There is also the assumption that the effects can technically be reversed and the features restored. Although it may not be practical or affordable to restore natural conditions for migrant birds, Coastal Wetlands and Islands, it may be reasonable to assume that with a commitment to resources the Nearshore Zone and Coastal Terrestrial Systems features could be restored and the threat reversed (Table 13).

Table 13: Threat assessment of housing and urban development and shoreline alterations to Lake Huron biodiversity features. Threats were ranked for each feature, when applicable, with separate rankings for scope, severity, and landscape context.

	Aerial Migrants	Coastal Terrestrial	Coastal Wetlands	Islands	Native Migratory Fish	Nearshore Zone	Open Water Ecosystem	Summary threat rating
Housing and Urban Development	H H V Very High	H H V Very High	H V V Very High	M V V High		H H V Very High		Very High
Shoreline Alterations	L L H Low	M M M Medium	M H H Medium	L M H Low		M M M Medium		Medium

Housing and Urban Development and Shoreline Alterations Conceptual Model

A conceptual model depicting causative linkages, contributing factors, opportunities, and associated strategies for housing, urban development, and shoreline alterations can be found below (Figure 18). Contributing factors can be grouped into six major themes that encompass the drivers of the threat of housing and urban development and shoreline alteration, described in more detail below:

- Social, Cultural, and Economic
- Environmental
- Political
- Resource Management
- Resource Information
- Awareness, Education, and Engagement

Social, Cultural, and Economic

Urban and coastal development has increased and this trend is expected to continue given the population increase and high demand for housing, second home and cottage development along the water front. Recent land use trends include shoreline sprawl, larger developments, and bigger homes with incompatible shoreline and habitat alteration practices. These demands on coastal areas are exacerbated by a lack of understanding and clarity regarding water rights and governmental responsibility and jurisdiction for regulating shoreline development.

Environmental

Shoreline residents have responded to sustained low water levels by dredging, infilling, extending docks, building piers, breakwaters, and blasting for boat access. Beach raking and removal of riparian vegetation has also resulted from lower water levels. These issues lead to ongoing perturbations beyond the initial impacts caused by development.

Political

Current policies are too permissive in their approval of development projects and decisions are not made at a scale that acknowledges and accounts for cumulative impacts. Although specific designations of particularly sensitive coastal areas should afford additional protections, there is a general lack of recognition of existing designations of Environmentally Sensitive Areas (ESAs) and Areas of Natural and Scientific Interest (ANSIs). In Ontario, policies guiding land use and development in the Provincial Policy Statement and Conservation Authorities Act do not consider cumulative environmental impacts; the same is evident on the U.S. side of the basin. Resources to identify and protect sensitive habitat are limited, both with respect to abating the threat of development and shoreline alterations specifically, as well as environmental protection generally. In addition, current regulations are not sufficiently protective of biodiversity; for example, there is a lack of regulation over loss of wetlands to agriculture.

Resource Management

There is no comprehensive management planning process that exists on a regional or binational level that harmonizes shoreline land use planning, policy, enforcement, ecosystem processes, and biodiversity conservation amongst multi-jurisdictional agencies. Cumulative and distant environmental impacts are generally not considered when regulating nearshore and coastal development. In addition, local planning offices lack capacity, and are too often understaffed, overworked, and inexperienced; access to and availability of information regarding comprehensive environmental planning, natural resource values and ecosystems services, and sensitive ecological areas are insufficient. As such, some areas of the Lake Huron shoreline are without planning and enforcement capacity; for example, there are gaps in the Conservation Authority jurisdiction on the Canadian side of the basin. Finally, resource management efforts to conserve important places and species rarely have explicit and strong links to aquatic ecosystems.

Resource Information

There is a general lack of research and monitoring information available to understand Nearshore Zone bathymetry, assimilative capacity of the Nearshore Zone, effects of sustained low/high water cycles, climate change related impacts, and cumulative effects of shoreline alterations (particularly with regard to impacts that are not immediate in space and time). Coastal Wetlands, migrant bird staging areas, and critical Nearshore Zone habitat remain to be mapped and evaluated for their ecological significance.

Awareness, Education & Engagement

Public and local stakeholder lack awareness of the importance of intact coastal, nearshore, and wetland ecosystems, cumulative environmental impacts of shoreline alterations within the context of littoral cells (regional sediment compartments), and the ecological goods and services that the Nearshore Zone provides. As such, they also lack awareness regarding their potential role in safeguarding these critical systems. Sadly, this lack of awareness is not limited to the general public, but is also pervasive among those policy and decision makers that ultimately determine the balance between where development and shoreline structures will occur, and where and whether coastal conservation will occur.

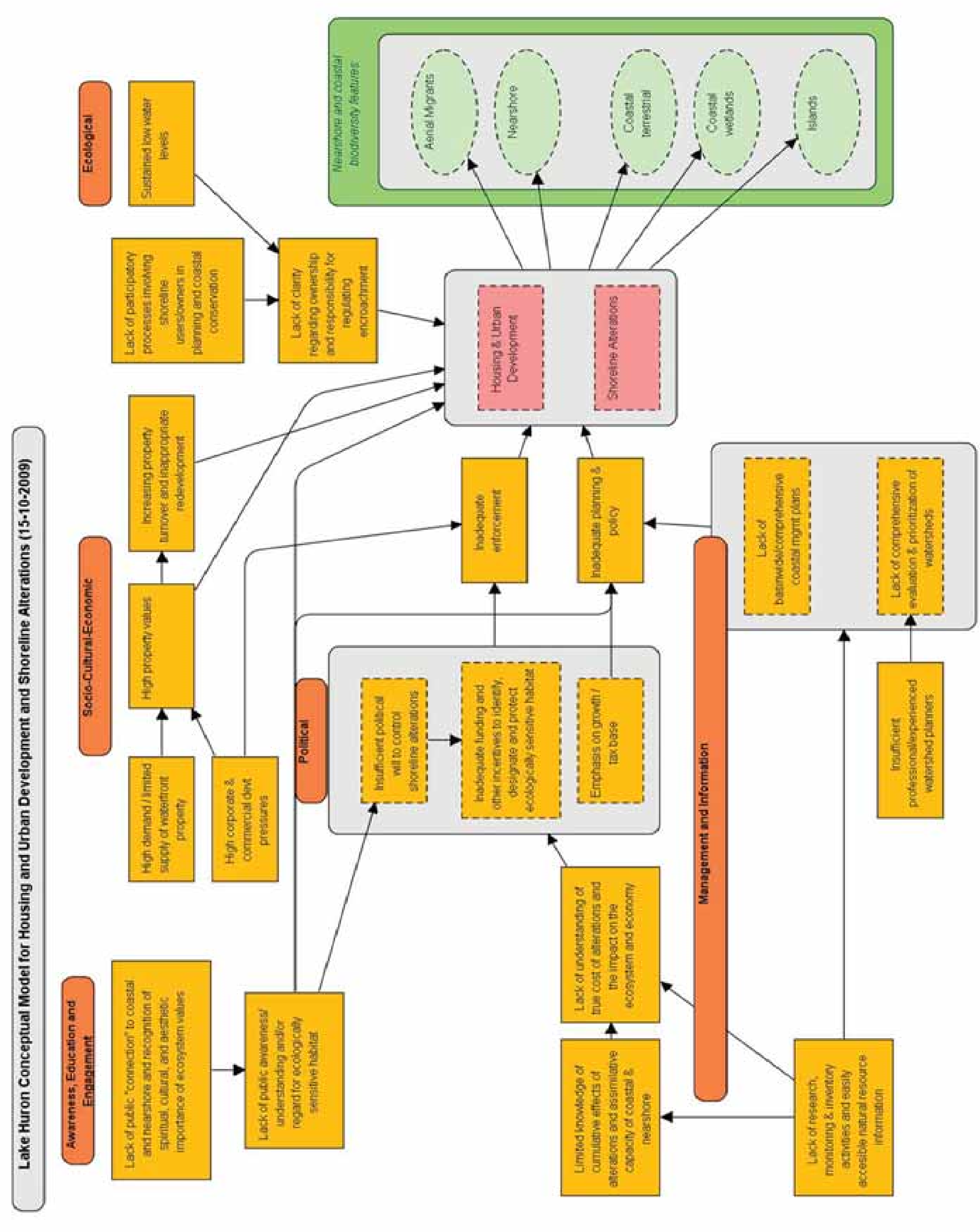

Figure 18: Conceptual model for housing and urban development and shoreline alterations.

5.2c Climate Change[4]

Why Is Climate Change A High-Ranking Critical Threat?

Global climate change is expected to lead to six major types of changes in Lake Huron: 1) increased annual averages in air and surface water temperatures (with greater extremes in hottest temperatures), 2) increased duration of the stratified period, 3) changes in the direction and strength of wind and water currents, 4) flashier precipitation (increases in the intensity of storms, and drier periods in between), 5) decreased ice cover, and 6) changes in lake levels. Clearly, these factors interact with one another, further complicating our ability to anticipate climate change trends and impacts, making this a very serious as well albeit uncertain threat. Nevertheless, below are some current and credible estimates of what we might expect to see in Lake Huron. Variability in climate change projections for a number of these factors underscores the need to incorporate a *range* of possible impacts on focal species and ecosystems, with positive and negative consequences of management actions compared across a range of plausible future scenarios.

Over the last century, the average global surface temperature has increased approximately 0.8°C, with increases of an additional 1.1 ° to 6.4°C or more projected by 2100 (Meehl et al. 2007, Trenberth et al. 2007). Like other regions at moderate latitudes, climate change projections for the Great Lakes region are somewhat higher than projections for the global average, and strongest changes are expected to be increases in summer maximum temperatures, and winter minimum temperatures (CCSP 2009). The rate at which these temperature changes are occurring suggests that many, if not most, species will experience climate change as a stressor that reduces survival and/or reproduction, and thus has strong potential to lead to population declines, or even extinction. The most recent Intergovernmental Panel on Climate Change (IPCC) report, suggests that 15-40% of species will be at increasingly high risk of extinction as global mean temperatures reach 2 to 3ºC above pre-industrial (or 1.2 - 2.2º C above current) levels (Field et al. 2007, based on work in Thomas et al. 2004). Further, summer surface water temperatures in the upper Great Lakes are currently increasing even faster than air temperatures (Austin and Coleman 2007, see Table 14). In addition to acting as current or future stresses on species, these temperature increases are triggering a whole range of system-wide impacts, including increases in wind and current speeds, shifts in wind direction, and increases in the duration of the stratified period (Waples and Clump 2002, Austin and Coleman 2007, Austin and Coleman 2008, Desai et al. 2009, Dobiesz and Lester 2009).

Table 14: Estimated rate of change in summer (July-September) temperature (T) and the duration of the stratified period for two locations in Lake Huron from 1979-2006 (from Austin and Coleman 2007).

	Air T 10^{-2}°C/yr	Surface water T 10^{-2}°C/yr	Start of the stratified season days/year earlier
Northern Lake Huron	7.6 ± 3.6	9.8 ± 4.5	0.89 ± 0.35
Southern Lake Huron	5.7 ± 3.1	7.4 ± 3.8	0.40 ± 0.29

Evaluating the impacts of temperature changes on the ecosystems and species of Lake Huron is a challenge, as we need to think about both the potential impacts of temperatures increasing at an accelerating rate, and about the potential for feedback loops, exceedance of critical thresholds, and the potential for tipping points (dramatic shifts in a ecosystem in response to an incremental change). For example, the observation that

[4] The following text for the Climate Change section is generally more detailed than other threat sections as climate change was investigated in depth in a complimentary workshop: The Nature Conservancy's 2009 Climate Clinic (for more information see: conserveonline.org/workspaces/climateadaptation/)

summer surface water temperatures have been increasing faster than summer air temperatures reflects a positive feedback on the warming rate of surface waters due to reductions in ice cover. While highly variable from year to year, ice cover on Lake Huron has been declining at an average of almost 2% a year since 1972 (Wang et al. in prep). Ice reflects energy from the sun, and insulates surface waters from the warming air, but melts more quickly when the air is warmer, which accelerates the rate of summer surface water warming (Austin and Coleman 2007 and 2008, Dobiesz and Lester 2009).

Similarly, to understand how climate change impacts a key process like lake stratification, we need to look at projected temperature changes relative to key thresholds; specifically, researchers predict the duration of stratification by estimating when surface waters will go above and below about 4ºC (McCormick and Fanenstiel 1999). Given the information above on increases in surface water temperatures, we should expect increases in the duration of the stratified period in Lake Huron, and indeed it has already increased by roughly two weeks in the upper Great Lakes since the middle of the last century (CCSP 2009). Air and water temperatures are expected to keep increasing at an accelerating rate, so we should expect to see even more changes in the timing of this key process.

While temperature trends are expected to continue upwards, there is much more variation in projections for precipitation. When groups of Global Circulation Model (GCM) projections are compared, the most notable result is the wide variety of projected changes in mean precipitation (e.g., increases and decreases, with shifts in patterns over time), although many “agree” on a projection of increases in winter and spring precipitation. With respect to extreme precipitation events rather than mean values, however, there is general agreement that the frequency of extreme rain events (intense storms) will increase, especially in the winter and spring. Trends over the last 50 years for the upper Midwest suggest a 31% increase in the amount of rain that falls in the top 1% of “very heavy” precipitation events, and this impact is expected to increase due to the fact that warmer air can hold more water (CCSP 2009, based on updates to Groisman et al. 2004). Related to these increases in intensity, we also expect increases at the other end of the extreme weather events spectrum, and periods between rain events will likely be drier, leading to summer droughts.

As a result of changes in temperature and changes in precipitation, lake water levels are also expected to change. Lake level forecasting based on most GCM projections for future temperature and precipitation regimes suggest drops in lake levels, although increases are also possible if precipitation shows strong increases (Angel and Kunkel 2009). Work by Angel and Kunkel using 23 GCMs reports a median value for projected changes by 2050 of a 0.23m drop for all three emissions scenarios they tested (low-B1, medium-A1B, and high-A2). However, this work suggest a wide range of possible futures, as the “lowest” 5% of model runs suggest a drop of 0.79 to 0.94m or more by 2050, and the “highest” 5% of runs suggest increases of 0.15 – 0.42m (B1 – A2) by 2050. Earlier work (Mortsch et al. 2006 citing work by Fay and Fan) suggests drops of 0.29 to 1.18m, and the recent US Assessment report show a figure based on Hayhoe et al. (in press) which suggests a decline in Lake Huron water levels by 2050 of roughly 0.6 m.

In terms of implications for biodiversity features, the direct impacts are primarily considered a threat because they are happening at such fast rates, and many species are not likely to be able to adapt, either due to limitations in physiology or mobility, or because anthropogenic changes in habitat seriously hinder adaptive responses. In general, most responses of species to changes in temperature can be categorized as changes in range or local abundance/viability, or as changes in timing of seasonal events (phenology). For a long-term shift into new areas to occur, there must be a way for species to move, a path for them to follow (e.g., connectivity), and a place to go that has climatic conditions that will permit individuals to survive and reproduce.

Changes in species' range boundaries and abundance patterns within the Lake Huron basin are of concern for several reasons. First, the rapid changes in climate described above are taking place in the context of a wide range of other impacts on these ecosystems, most notably habitat loss and fragmentation, such as coastal development, and the presence of dams and barriers. Even in areas where we have large expanses of intact ecosystems, increasing temperatures can make wetland habitats more fragmented as some patches dry out, an impact that can be accelerated if lake levels decline.

Second, range and abundance changes are of concern because species that are not able to disperse will have the added stress of species from lower latitudes (both native and non-native invasive) invading their habitats. So, individuals at the southern end of their species' range have the potential to be stressed both by climatic conditions that are becoming less and less favorable, and by species that move in from warmer areas and are less challenged by the same climatic factors. The species moving in may directly compete for key resources, and also may contribute to the decline of resident species by spreading diseases and parasites.

Third, we are concerned about range and abundance shifts because species movements will often be independent of shifts of other species. We expect species to shift independently, as the set of constraints that describe the habitat and ecological niche for each species (factors like water temperature, food availability, sediment type, and stream flow characteristics) is unique. In effect, we expect to see the "tearing apart" of sets of species that typically interact, and many of these interactions may be critical to the survival of one or more of the interacting species.

Concern about key species interactions also leads us to examine the potential for phenological mismatches, or disparate changes in the timing of seasonal events. For many organisms, seasonal changes in temperature act as cues that trigger transitions in the species' seasonal cycle (e.g., the transition from egg to larvae, or breaking of dormancy for planktonic species). The dominant cue for some seasonal changes, like the start date for migration for many birds, is a change in day length (Berthold 1996), but temperature can still have a strong influence on the timing of migration by influencing the rate at which birds travel from the wintering grounds to breeding habitats. In addition to directly triggering changes in timing, warming trends can impact species by influencing other key seasonal events that trigger changes in their seasonal cycles, such as timing of snowmelt, flooding, or lake stratification.

The potential importance of phenological mismatches may be easiest to imagine in ecosystems where attainment of a threshold temperature cues the emergence of leaves of a dominant wetlands plant. In such an ecosystem, a shift in the timing of spring warming that alters when these plants grow or bloom could represent a key change in the foundation of the food web that determines energy flows throughout the entire ecological system. If other species in the same ecosystem do not shift in the same direction and at a similar rate, they may be at a strong disadvantage in terms of their ability to survive and reproduce relative to other species with similar resource requirements. As noted above, conditions in the Great Lakes are changing rapidly (increasing temperature, longer stratified period, stronger currents), suggesting a high potential for species to respond at different rates, and contribute to disruption of entire food webs.

Affected Features

Climate change poses a threat to every biodiversity feature, with the highest degree of threat for Coastal Terrestrial Systems and the least severe degree of threat for native migratory fish (Table 15). Below is a description of how climate change can be expected to impact each biodiversity feature.

Coastal Terrestrial Systems were deemed to have a 'very high' level of threat from global climate change. Factors influencing this ranking included the lack of connectivity in many terrestrial coastal zones due to changes in land use, and the natural patchiness of some habitat types. This reduced connectivity acts as a hindrance to key processes (e.g., dispersal, pollination/gene flow) that help systems and species be more resilient to changes, and also inhibits range shifts by removing key pathways to cooler sites. This conservation feature incorporates a suite of rare species that are of high conservation concern, and many of these have very specific habitat requirements, which, along with the fragmented habitat, suggest high risk from climate change. Habitats along the northern shore of Lake Huron are analogous to systems on mountain tops; there is no habitat to the north that species can shift toward without crossing inhospitable areas. Other key concerns include stresses related to invasive species; for example, if lake levels do drop, many newly exposed areas will be at risk of invasion from *Phragmites* and other non-native invasive plants. Coastal Terrestrial Systems are also likely to be exposed to higher drought stress in the summer, and more intense rain events, which may lead to erosion and reduced viability of sensitive coastal systems like wetlands. Further, changes in wind and current patterns are likely to lead to changes in key physical processes that shape coastal communities. As with all of our conservation features, there is also the potential for phenological mismatches that reduce the viability of key species.

Key concerns in the Nearshore Zone aquatic ecosystem include impacts related to hypoxia, as warmer water temperatures and a longer stratified period are expected to lead to higher summer oxygen depletion. These areas may also show phenological mismatches that influence food web dynamics, as some species are likely to respond more quickly to changes in temperature and the timing of stratification than will others. Further, changes in wind and current patterns are likely to lead to changes in sediment movement patterns, and the distribution of Nearshore Zone habitat types. Nearshore Zone ecosystems are also likely to be impacted by many indirect effects related to more intense storm events, and increased potential for extended dry periods between rain events. In particular, this biodiversity feature is likely to be impacted by failures of infrastructure related to stormwater and sewage handling, and to increased exposure to sediments, fertilizers, and other chemicals as more water runs off from nearby farms into rivers and coastal zones.

In addition to the aquatic environment, shoreline configuration, seasonal and decadal water level fluctuations, and bedrock geology, climate plays a significant role in structuring and maintaining Coastal Wetlands. Climate change, through warmer air temperatures, increases in evaporation, and changes in precipitation and snow cover, is expected to significantly alter the hydrology over the next 50 years, relative to the last 150 years (Mortsch et. al., 2006). Changes in the mean lake level, annual range, and seasonal cycle as well as the timing, amplitude, and duration of water levels are expected to occur, although there is high uncertainty regarding the magnitude, timing, and direction of changes (see above). Of the possible changes, the most critical impact is projected to result from decreased water levels, resulting in an alteration of the current area, distribution and abundance of Coastal Wetlands (Mortsch et. al., 2006). The impacts of climate change will potentially exacerbate continuing direct human disturbances such as dredging and filling, water diversion, and pollution (Kling et. al. 2003). Potential impacts of declines in lake levels on Coastal Wetlands have received relatively more attention that other aspects of climate change impacts in the Lake Huron basin.

Climate change poses a 'high' threat to Aerial Migrants due to loss of key habitats or food resources, and phenology mismatches. Species that require wetland habitats as habitat along their migration route are likely to be most vulnerable, as these habitats are potentially impacted by many different climate factors. In particular, decreases in water level may reduce coastal wetland area (especially where wetland plants are unable to migrate lakeward) and thereby reducing the amount of available habitat for area-sensitive species of waterfowl that use these areas for staging during migration. Climate induced water level changes may also affect foraging habitat if wetland plant communities and vegetation-dependent food resources (e.g., invertebrates, herptiles) change. Several researchers (Marra et al. 2005, Visser and Both 2005, Visser et al. 2006, Both et al. 2009) have suggested that changes in bird migration phenology may be slower than the responses of many of the plants and insects at the stopover sites upon which these birds depend, potentially leading to a mismatch between their stopover habitat use and food availability (e.g., aquatic insect hatches, Ewert and Hamas 1995, Smith et al.1998). We might expect similar phenology mismatches for dragonflies and other insects, as again the higher rate of warming of surface waters relative to air suggest the potential for differential responses by species that are key elements of habitat or food sources.

Islands are also expected to have a 'high' degree of threat to climate change impacts, largely due to concerns about the lack of connectivity for relatively immobile species (e.g., plants, reptiles, some insects, and some fish that may avoid movement through unfavorable habitats) that would potentially benefit from northward movement. Also, changes in ice cover and duration (e.g., potential for scouring), along with changes in wind pattern and currents, may lead to changes in the disturbance regime that shapes island coastlines, potentially reducing habitat quality for some species that use these areas. On the "opportunities" side, if lake levels decline, most Islands would be expected to increase in area, or to even become connected. However, this connection, in addition to the potential for range shifts in mobile species, may lead to colonization of Islands by species that out compete current native flora or fauna.

Anticipated impacts on the open water benthic and pelagic biodiversity feature are many. The differences in temperature, light availability, and other factors that occur as a result of stratification provide a diversity of habitats within the upper Great Lakes, which allows species with a wide variety of temperature and other habitat requirements to persist. The timing of stratification, as well as the timing of the fall "turnover", when the oxygen-rich surface waters cool and increase in density, and finally sink down and mix with the others, can be a critical factor influencing the viability of lake species, especially cold-water fish. Although specific impacts of these changes in Lake Huron are at this point unknown, impacts of this magnitude (e.g., changes on the order of weeks or months) are likely to have a strong impact throughout lake foodwebs (Magnuson et al. 1997, Brooks and Zastrow 2002, Lehman 2002).

Each native migratory fish species has a characteristic preferred temperature and, as ectotherms, the body temperature of a fish matches closely the temperature of the water in which it lives. As a result, rates of food consumption, metabolism, and growth rise slowly as the preferred temperature is approached from below, and drop rapidly after it is exceeded until reaching zero at the lethal temperature. In addition to this strong life history dependence on suitable water temperatures, fish will respond strongly to climate-induced changes in water volume, water flow, and water temperatures, either by shifts in distribution or in overall productivity (Kling et al. 2003). Although several research efforts (i.e., Rahel 2002) have developed range change estimates for fish, Jones et al. (2006) found that projections of the potential impact of climate change on Lake Erie walleye based simply on water temperature change were very different from results incorporating changes in climate-sensitive factors such as water levels and light penetration. This work relied upon decades of research on this fish's habitat needs and biology, and illustrates that for well-known species like walleye, the challenge to managers and conservation practitioners may focus on characterizing a complex set of direct and indirect climate-related changes that may interact and influence species survival. For most other species, a lack of baseline information from which to even begin the process of understanding potential impacts is often the most daunting challenge.

Table 15: Threat assessment of climate change to Lake Huron biodiversity features. Threats were ranked for each feature, when applicable, with separate rankings (Low, Medium, High, Very High) for scope, severity, and landscape context (respectively stacked vertically within each box along the left side) and "rolled up" into an overall threat ranking for each feature. For more details see Section 5.1 Threat Assessment Methodology.

	Aerial Migrants		Coastal terrestrial		Coastal wetlands		Islands		Native migratory fish		Nearshore Zone		Open Water Ecosystem		Summary threat rating
Climate Change	V M V	High	V H V	Very High	V M V	High	V M V	High	V M H	Medium	V M V	High	V M V	High	Very High

Climate Change Conceptual Model

A conceptual model depicting causative linkages, contributing factors, opportunities, and associated strategies for climate change can be found below (Figure 19). These factors generally fall into two categories: 1) direct impacts of climate change on biodiversity features; and 2) indirect impacts of climate change on biodiversity features by exacerbating other critical threats. These indirect impacts are likely to be some of the more promising areas for climate change adaptation strategy development, as we often have tools and methods in place to help us abate these threats and may most easily be able to redouble those efforts as these threats become more pronounced due to climate change. In contrast, it is often more challenging to address climate changes' direct effects, although we can certainly work toward helping to ensure that ecosystems are as connected and resilient as possible such that species can move and remain viable under current and future climate conditions.

Further, we need to consider both current and future indirect impacts that are likely to arise as human societies respond to climate change. Many types of actions, such as those that lead to shifts in land use, or increases in water extraction, could lead to increased stress on lake ecosystems. For example, one key threat to the health and biodiversity of the Great Lakes is the conveyance of pollutants, nutrients, and sediments into Nearshore Zones during storm events. As noted above, although projections for *average* precipitation patterns in the Great Lakes region show wide variation, there is strong agreement that the intensity of peak storm events will increase (CCSP 2009). We already know that to restore many Great Lakes habitats, we need to reduce these kinds of inputs, and that much of our infrastructure (e.g., for handling stormwater and sewage) and farm practices need to be improved. Climate change increases the urgency of these needs. Further, climate change is likely to cause more pressure to withdraw water from the Great Lakes, as drought stress is projected to increase both locally, and globally. Sustained water level decreases have already resulted in shoreline alteration in the form of dredging, infilling, beach grooming, and dock extensions. We can expect shoreline residents to modify coast lines to suite their needs unless effective policies and regulations are put in place.

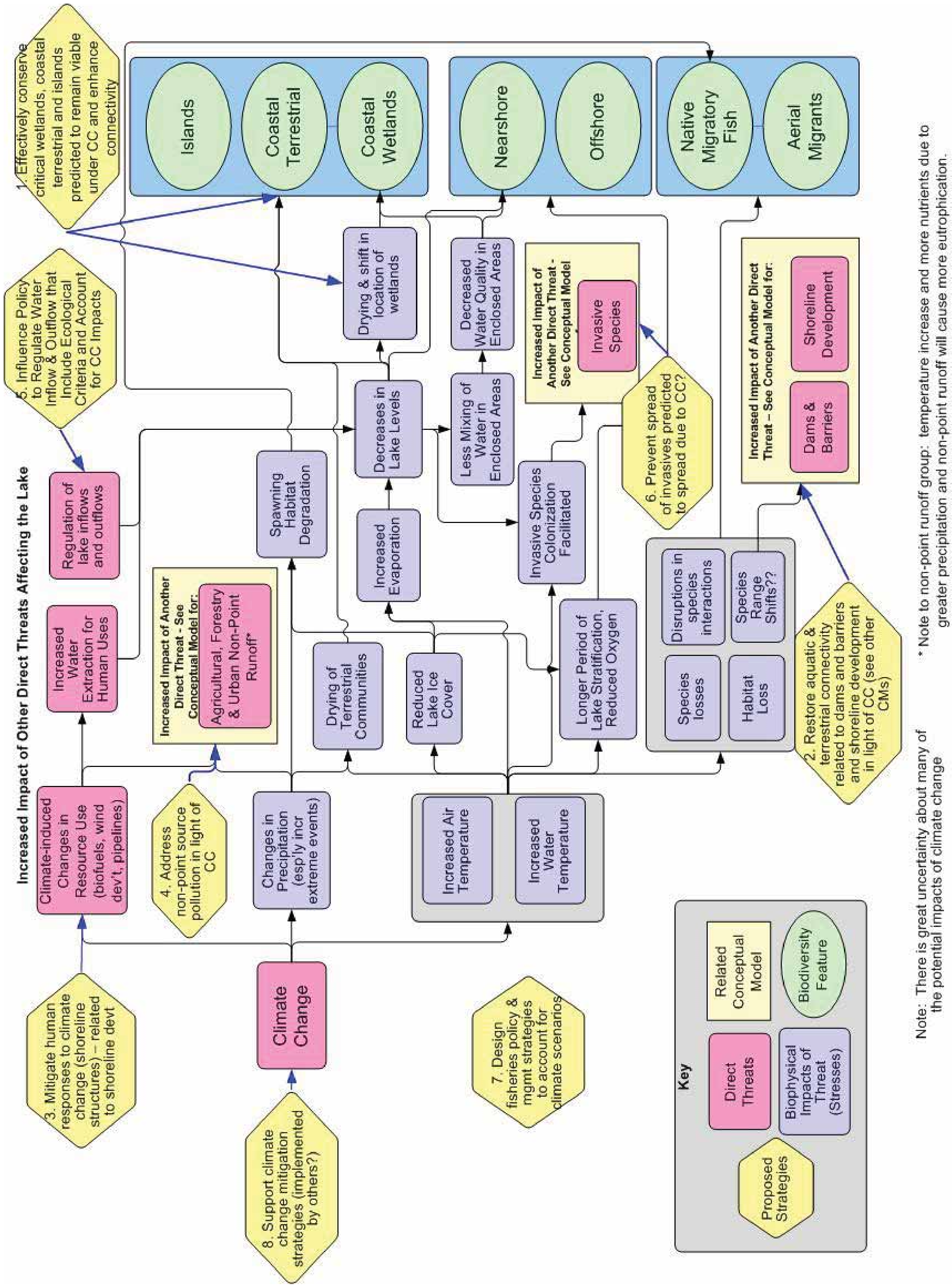

Figure 19: Conceptual model of the threat of climate change.

5.2d Dams and Barriers

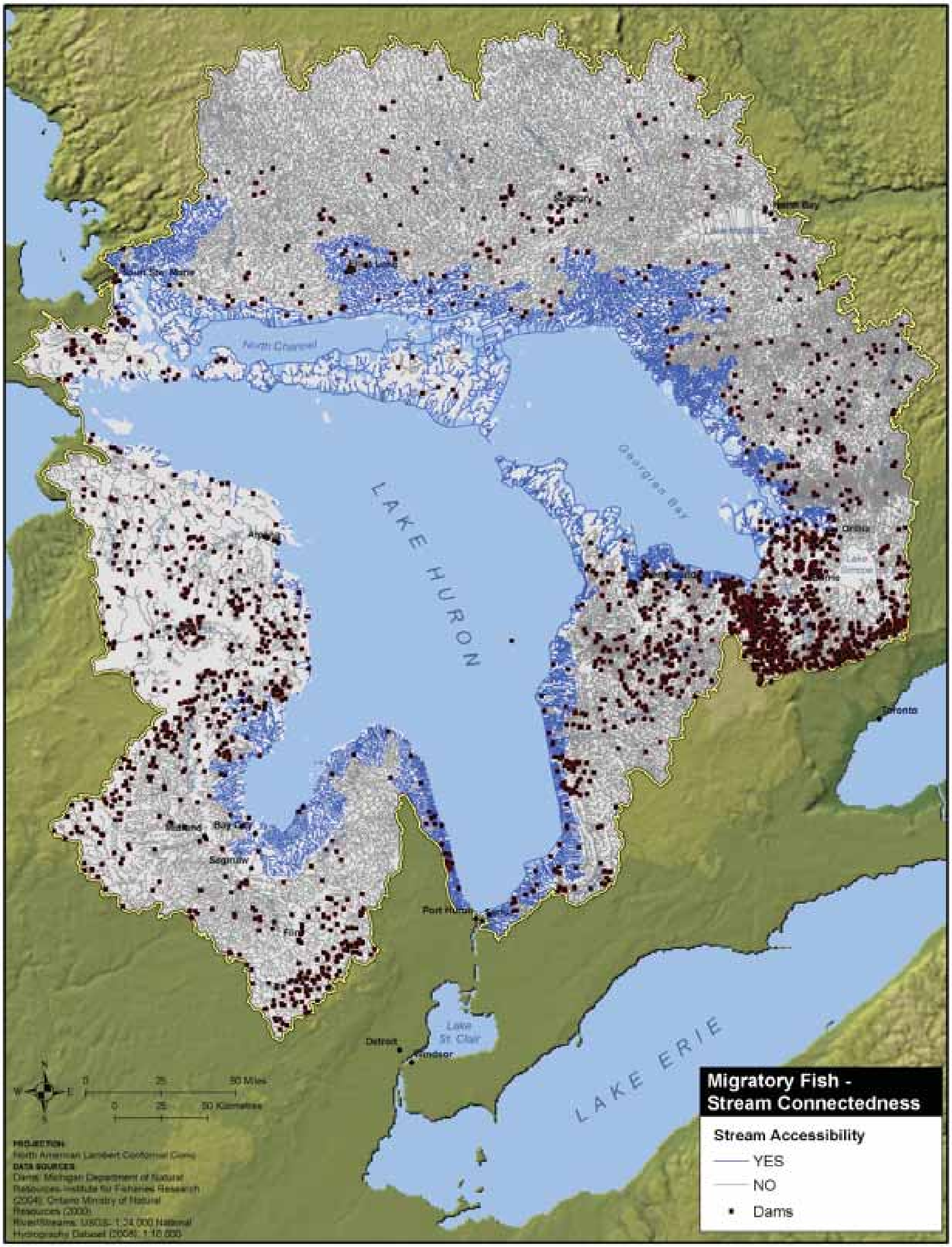

Figure 20: Location of dams and accessible tributaries.

Why Are Dams and Barriers A High-Ranking Critical Threat?

For the purpose of this Strategy, dams and other barriers are defined broadly as anthropogenic structures that alter the hydrology of tributaries. Recognizing that different types of structures pose different degrees of stress, we use the term 'dams and barriers' to encompass hydropower dams, lowhead dams, road-stream crossing/culverts, and water-control structures (e.g. locks, dikes). Natural obstructions (e.g. falls) are not included. Given the variety of dams and barriers, this threat can affect the biodiversity of Lake Huron through different mechanisms and to different extents.

Tributaries provide critical habitat for fish and wildlife (Crosbie and Chow-Fraser 1999, Liskauskas et al. 2004, Fielder et al. 2008, LHBP 2008); for over one-third of Great Lakes fishes, tributaries provide critical spawning and nursery habitats (Liskauskas et al. 2004, Fielder et al. 2008.). The installation and management of dams threatens the diversity of native fish in Lake Huron by restricting or eliminating connectivity between the lake and critical spawning, nursery, and overwintering habitats. Before the 1800's, over 10,000 km (more than 6,000 miles) of tributary habitats were accessible to Lake Huron fish (Liskauskas et al. 2004, LHBP 2008); a small fraction of that habitat is now accessible (Figure 20). Indeed, 86% of major tributaries are no longer connected to the Lake Huron basin (Gebhardt et al. 2005). This loss of tributary habitat has resulted in significant declines in native fish populations in the lake, such as lake herring, yellow perch, walleye, lake sturgeon, river redhorse, black redhorse, eastern sand darter, and channel darter, (Liskauskas et al. 2007, Eagle et al. 2005, Bredin 2002).

Tributaries also provide water, nutrients, and sediment to Lake Huron and its coastal and nearshore ecosystems (Crosbie and Chow-Fraser 1999, LHBP 2008). The proliferation of mill dams, and later hydropower facilities, also has altered in-stream flow and temperature, as well as nutrient and sediment regimes between the nearshore, coastal tributaries, and the open waters of the lake. Dams and barriers can also physically alter stream channels and habitats by causing increased scouring, extreme flows (Liskauskas et al. 2007), and changes in temperatures that can degrade or eliminate spawning and nursery habitats. The downstream and upstream effects of a single dam can alter the character of an entire watershed (Postel and Richter 2003). These regime changes have also resulted in a loss of river delta wetlands (Bredin 2002). Most cold water tributaries draining into U.S. waters are inaccessible to the lake due to barriers (Liskauskas et al. 2007). All of these changes and effects are likely to become even more severe in light of climate change.

Road-stream crossings can negatively impact both fish migrations and ecological processes, but to a lesser extent than dams. This aspect of the dams and barriers threat is often much more localized in nature and is addressed on a more local level.

Alleviating this threat is not straightforward as there are also perceived ecological benefits to some dams and barriers. For example, dams and barriers currently limit the spread of some Great Lakes invaders. Lake Huron supports the largest population of sea lamprey in the Great Lakes (Liskauskas et al. 2007), and dams and low-head barriers are a major control mechanism used by managers. Some dams and barriers may also play a role in limiting the spread of other invasive species such as round gobies, tubenose gobies, and viral hemorrhagic septicemia. Additionally, dams and barriers, in some instances, are protecting the native stream assemblages from competition and physical disturbance of substrates from non-native salmonids (Bredin 2002). Hence, decisions about removal of dams and barriers in Lake Huron must balance competing interests and goals, which may not always be explicit.

Affected Features

Dams and barriers pose the greatest threat to Native Migratory Fish (high in the threat ranking matrix; Table 16). Scope and irreversibility of this threat were considered high, while severity was ranked very high. For sturgeon and walleye, tributary habitats are a limiting factor to increasing population numbers (Fielder et al. 2008). Most of the historic spawning areas for sturgeon are currently blocked by dams (Liskauskas et al. 2007). The Lake Huron Binational Partnership identified dams 'as the *single most important impediment to recovery of lake sturgeon*' (LHBP 2008).

Dams and barriers were also ranked as a high threat to the Nearshore Zone. The Nearshore Zone is greatly affected by riverine inputs of nutrients and sediments, and dams and barriers alter the delivery (both timing and quantity) of these inputs. In addition, most Great Lakes river-spawning fish spend the remaining stages of their life in the Nearshore Zone. As a result, vastly suppressed populations of these species, due to lack of access to spawning habitat, can result in broad shifts in Nearshore Zone community structure and food web interactions. The scope and severity of this threat were ranked as high and irreversibility was considered medium.

Similar to observed impacts in the Nearshore Zone, but to a lesser degree, some Coastal Wetlands are sustained by riverine inputs of sediments. Hence dams and barriers were ranked as a low threat to Coastal Wetlands. The severity and irreversibility were considered high for the impact of dams and barriers on Coastal Wetlands, but scope was low or limited.

Table 16: Threat assessment of dams and barriers to Lake Huron biodiversity features. Threats were ranked for each feature, when applicable, with separate rankings (Low, Medium, High, Very High) for scope, severity, and irreversibility (respectively stacked vertically within each box along the left side) and "rolled up" into an overall threat ranking for each feature. For more details see Section 5.1 Threat Assessment Methodology.

	Aerial Migrants	Coastal terrestrial	Coastal wetlands	Islands	Native migratory fish	Nearshore Zone	Open Water Ecosystem	Summary threat rating
Dams and Other Barriers			L H H Low		H V H High	H H M High		High

Dams and Barriers Conceptual Model

A conceptual model depicting causative linkages, contributing factors, and opportunities for dams and other barriers can be found in Figure 21. Two major contributing and conflicting factors that currently drive this threat, namely: 1) pressures or influence to keep, install, and repair dams and barriers, and 2) pressures to remove or reduce effects of dams and barriers. In both cases, there is currently a lack of information in support of strategic and coordinated management of dams and barriers. The cumulative impact of dams and barriers is also often unknown and rarely acknowledged in decision-making (this is inherent in factors that seek to abate this threat like fisheries management and ecological restoration under pressure to remove, but not well incorporated in decision-making that perpetuates the threat (i.e., pressures to keep/install/repair dams/barriers).

There are several societal and resource management needs to maintain or build new dams and barriers, including:

- non-native aquatic invasive species control;
- hydropower generation;
- local values (which encompasses aesthetics, recreation, and water takings/diversion);
- controlling upstream movement of toxics (perceived/potential risk to humans, birds); and,
- cost of dam and barrier removal.

Maintenance of dams and barriers in some instances is a management tool to control populations and spread of non-native aquatic invasive species and is motivated by current fisheries management needs, sport and commercial fisheries interests, and the needs of threatened and endangered species. Hydropower generation is driven by existing industry and the power grid as well as new pressures to pursue carbon-neutral forms of power generation.

Conversely, there are several reasons to remove or mitigate the negative impacts of dams and barriers:

- fisheries management for economically important species and listed species;
- ecological restoration and ecosystem services;
- liability associated with dam failure (public safety, ecosystem impacts); and,
- inappropriately installed and placed barriers.

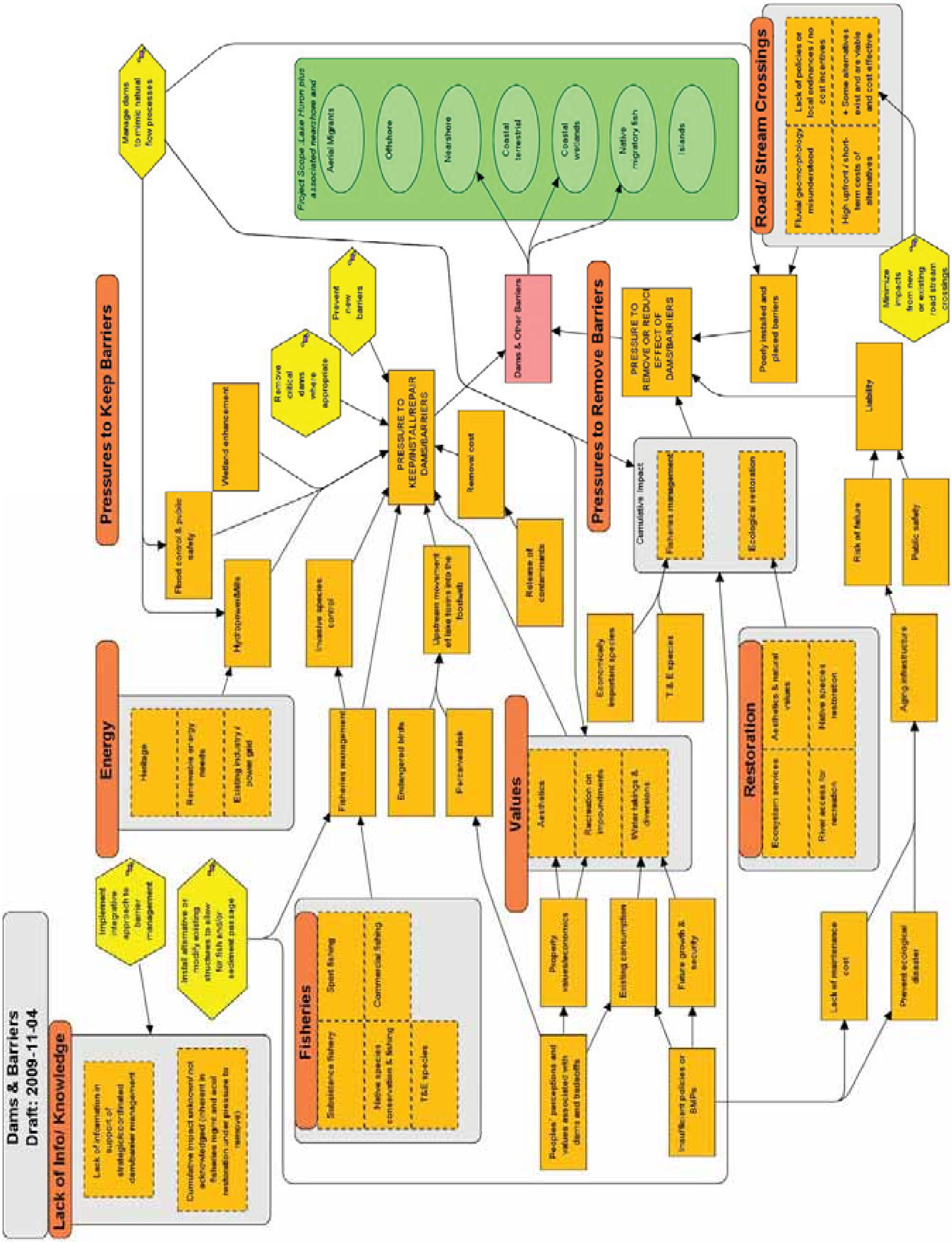

Figure 21: Conceptual model for dams and other barriers threat.

5.2e Agricultural, Forestry, and Urban Non-Point Source Pollution

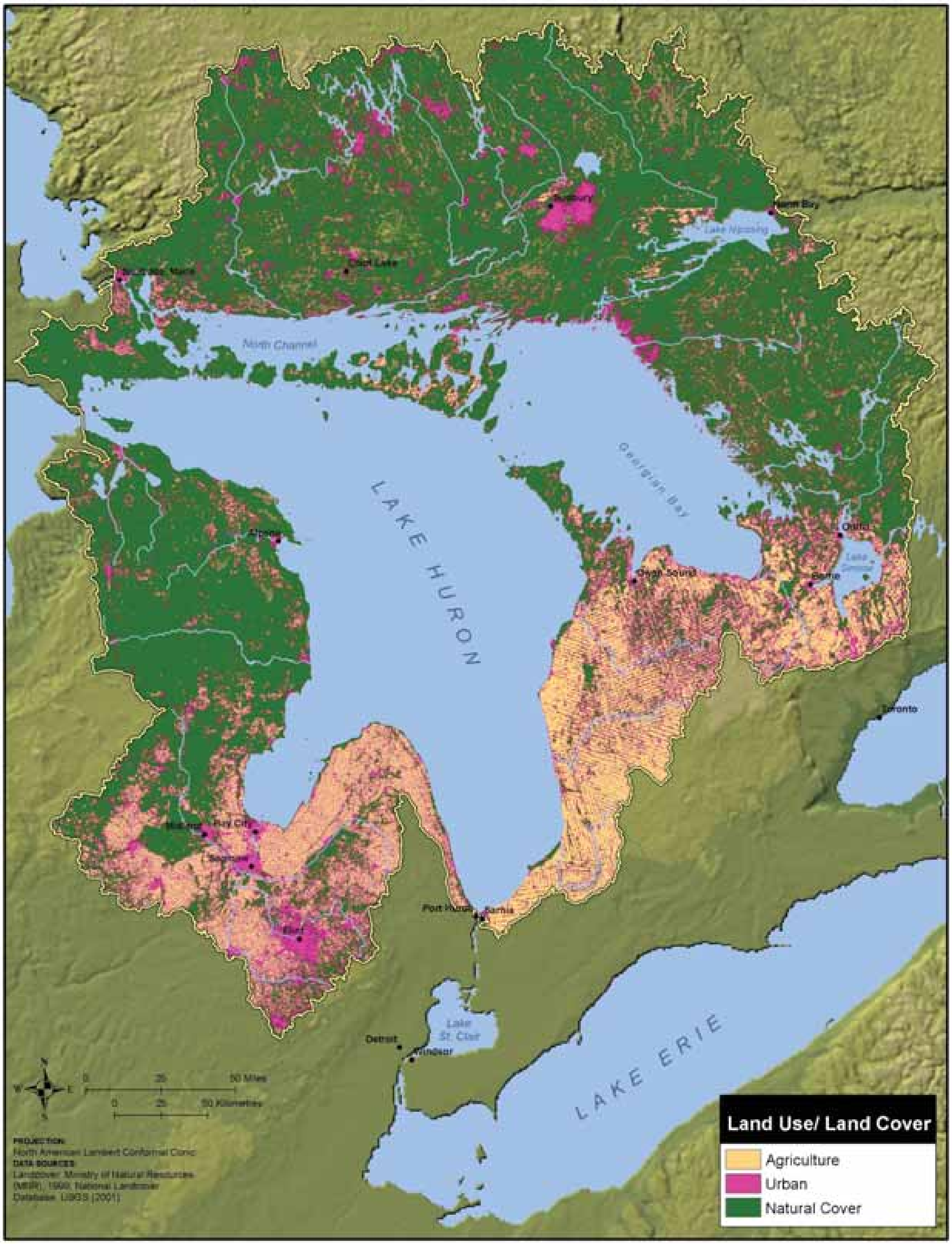

Figure 22: Land use/land cover types contributing to non-point source pollution.

Why Is Agricultural, Forestry, And Urban Non-Point Source Pollution A High-Ranking Critical Threat?

Non-point source (NPS) pollution generally results from diffuse movement of rainwater and snowmelt across the landscape into surface waters. As water moves across the landscape, nutrients, sediment, and other potential pollutants are encountered, are dissolved or suspended by the water and carried into surface waters. This form of pollution cannot be traced to a specific point and contains sediment, chemical, or nutrient contaminants that exceed natural baseline levels and, as a result, degrades water quality and associated biological communities in surface waters. Anthropogenic activities such as clearing of land for agriculture or development, fertilization, and land drainage have increased water runoff and the amount of pollutants that water runoff encounters NPS pollution will hereafter be used to refer to both changes in the timing and extent of runoff (altered hydrology) and in the pollutant loadings carried by the runoff, resulting from anthropogenic sources related to agricultural, urban, or forestry practices.

Non-point source pollution is generally considered a critical threat across much of the Lake Huron watershed (LHBP 2008; Figure 22). In parts of the southwestern lake basin, especially Saginaw Bay, it is much more prominent and has contributed to severe degradation of many Nearshore Zones and Coastal Wetlands (GLRC 2005). In northern Lake Huron and Georgian Bay, it is considered a threat that has caused localized degradation, primarily through scattered residential development, and threatens to significantly contribute to impairment if not held in check (Bredin 2002). While most of the watershed is in forest land cover (66%), agricultural (22%) and residential/industrial (10%) land uses are generally considered to be more significant contributors of NPS pollution than forestry (Bredin 2002).

Non-point source pollution, in particular from incompatible agricultural practices and residential and urban development, has already severely degraded Nearshore Zone and Coastal Wetlands in some areas, particularly Saginaw Bay and the southern portions of the basin (Bredin 2002, Niemi et al. 2009). Expansion of residential or urban development threatens to seriously degrade many other areas (Bredin 2002), including very high quality areas in northern Lake Huron and Georgian Bay (Palmer et al. 1998). In addition, Dreissenids have further complicated nutrient dynamics and the contribution of excessive phosphorus loadings to Nearshore Zones (Hecky et al. 2004). For some biodiversity features, such as Coastal Terrestrial Systems and Native Migratory Fish, the severity of this threat is more moderate.

The irreversibility of this threat is generally considered to be high, but some aspects are more reversible than others. While agriculture is likely a permanent component of the basin's economy, NPS pollution from agriculture can be minimized through conservation and best management practices (BMPs) that decrease sediment and nutrient loading (LHBP 2008). As a result, NPS pollution is generally considered reversible with a reasonable (sometimes substantial) commitment of resources. Incompatible residential or urban development, however, can be more difficult to alleviate once it occurs because of the prominence of resulting impervious surfaces (Master et al. 1998). Therefore, NPS pollution from development is generally considered to have higher irreversibility that is not practically affordable in many circumstances.

Affected Features

Non point source pollution poses the greatest threat to Nearshore Zone and Coastal Wetland features (Table 17). For these biodiversity features, scope, severity, and irreversibility were all considered high; NPS pollution is clearly a major driver for why biological integrity scores decline for Nearshore Zone and Coastal

Wetland features with increased coastal and watershed residential/urban development and agricultural land use (Lougheed et al. 2001, Uzarski et al. 2005, Niemi et al. 2009).

While NPS pollution also impacts native migratory fish, it represents a more moderate threat relative to dams and barriers. For example, walleye recovery in Saginaw Bay is dependent upon access to spawning habitat that is currently unavailable above dams, however, much of that habitat is also impaired by sedimentation, so addressing NPS sediment delivery to Saginaw Bay tributaries is also important to Native Migratory Fish (MDNR 2009). Altered hydrology is particularly important as a direct stressor to Native Migratory Fish since they spawn in rivers where the timing, extent, and variability of streamflow can greatly alter spawning habitat conditions.

Finally, NPS pollution also poses some threat to the Lake Huron Open Water Ecosystem and some Coastal Terrestrial Systems habitats. If agricultural and urban land uses expanded substantially, there is risk that Lake Huron Open Water Ecosystem nutrient regimes and food web structure could be impacted. However, currently NPS pollution impacts to the Lake Huron Open Water Ecosystem are minimal (Dobiesz et al. 2005, EC and U.S. EPA 2007). Coastal Terrestrial Systems features overall are threatened by NPS pollution at a low level, but this is because most Coastal Terrestrial Systems communities are generally not threatened by NPS pollution. For those that are, such as coastal fens, NPS pollution can pose a substantial threat resulting in habitat loss (from sedimentation) or altered community structure (from nutrients) (Detenbeck et al. 1999, Cohen and Kost 2008).

Table 17: Threat assessment of non-point source pollution to Lake Huron biodiversity features. Threats were ranked for each feature, when applicable, with separate rankings (Low, Medium, High, Very High) for scope, severity, and landscape context (respectively stacked vertically within each box along the left side) and "rolled up" into an overall threat ranking for each feature. For more details see Section 5.1 Threat Assessment Methodology.

	Aerial Migrants	Coastal terrestrial		Coastal wetlands		Islands	Native migratory fish		Nearshore Zone		Open Water Ecosystem		Summary threat rating
Non-Point Source Pollution		L M M	Low	H H H	High		M M M	Medium	H H H	High	V L H	Low	High

Agricultural, Forestry, and Urban Non-Point Source Pollution Conceptual Model

A conceptual model depicting causative linkages, contributing factors, opportunities, and associated strategies for Lake Huron NPS pollution from three primary sources (agricultural, urban/rural, and forestry) can be found below (Figures 23-25). In Lake Huron, NPS pollution most commonly results in pollution from sediment, nutrients, or chemicals such as pesticides, antibiotics, or hormones. Altered hydrologic conditions play a major role in contributing to high loadings of these pollutants, and can also directly cause NPS impacts, particularly at river mouths or for migratory fishes. Each of these pollutants is further compounded by altered hydrologic regimes within the basin, which generally increases the rate and volume of water transported downstream, and can play a major role in driving pollutant loadings. Altered hydrology from NPS sources also directly impacts biodiversity features. Factors contributing to increased sedimentation, nutrient pollution, altered hydrology, and other chemical pollution were divided into agricultural, urban/rural, and forestry sources.

Agricultural NPS pollution results primarily from incompatible agricultural management practices and incompatible ditching and tiling practices, which are ply driven by large-scale socio-economic factors. More specifically, agricultural row-crops have generally moved toward larger fields without fence rows or riparian vegetation, and without seasonal vegetative cover (e.g., pasture or cover crops). This has resulted in decreased water infiltration and increased runoff, as well as higher wind erosion and greater amounts of sediment and nutrients washing into streams. Best management practices to minimize impacts of these trends are only occasionally adopted, and generally in a patchwork fashion. One reason for this is that there is often not sufficient technical support staff to adequately facilitate enrollment in BMP funding programs (e.g., Farm Bill in the U.S.) and there is resistance to targeting money into specific, strategic areas due to political pressure for taxpayer funding to be distributed evenly. Global trends, such as moves toward biofuels, influence commodity prices and can complicate efforts to promote conservation practices. However, biofuels offer potential conservation opportunities if cellulosic technologies and associated markets are developed to promote perennial vegetation cover. Altered hydrologic regimes from excessive ditching and tiling compounds non-point source pollution problems. High density livestock, which is increasingly becoming an issue in localized areas (e.g., Saginaw Bay along Michigan's "thumb"), are a NPS issue because their waste is often applied to adjacent fields at incompatible concentrations or at times that are susceptible to high runoff potential. Aquaculture, which is a significant industry in Georgian Bay (Masser and Bridger 2007), can be a significant source of nutrients and eutrophication (Hughes 2006). There are indications that it is already a problem locally in Georgian Bay (Schiefer et al. 2006) and may be of increasing significance if the industry continues to grow, as projected (World Wildlife Fund Canada 2003.

Urban and rural NPS pollution results primarily from inputs from concentrations of septic systems, lawn fertilization, construction, impervious surfaces, and land drainage. Septic systems become significant problems when they occur at high concentrations and when they are in disrepair. Given the prevalence of homes with septic systems along much of Lake Huron, septic systems are often an important local source of nutrients and other pollutants. Lawn fertilization may also be a significant source of phosphorus at some locations. Like agriculture, urban land uses result in wetland drainage and ditching which decreases assimilation capacity that wetlands normally provide and increases transport of pollutants to Lake Huron. Construction projects often contribute large amounts of sediment to streams and resulting urban development (parking lots, structures, roads) increases impervious surfaces, which reduces infiltration and increases runoff, further altering hydrology and increasing transport efficiency of pollutants downstream. Urban sprawl, or the spread of urban areas into rural and natural areas, is a significant cause of urban development problems. Pollution from combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) are considered point-source pollution and therefore were not addressed as part of NPS pollution. CSOs and SSOs contribute to localized pollution in Lake Huron, including as a potential major source of bacterial contamination (Lake Huron Binational Partnership). But even in problem areas, non-point sources contribute the majority of nutrient pollution (Saginaw Bay Coastal Initiative 2009, He and DeMarchi 2010).

Forestry NPS pollution results from incompatible practices that result in significant base soil exposure or compaction that leads to increased sedimentation or runoff (or both) into tributaries. Examples include large clearcuts, significant forest clearing in or near riparian areas, excessive soil disturbance through heavy equipment operation or dragging of logs on slopes or in riparian areas, and poorly designed stream crossings. Better implementation of forestry BMPs that minimize these impacts will largely address forestry NPS sources. Factors that contribute to poor BMP adoption include a lack of incorporation of BMPs into management plans or a failure to follow management plans to increase profits. Global markets can also influence forestry NPS contributions, if the market demand for wood products significantly increases the scale of logging activities and increases incentives to harvest that are incompatible with BMP implementation. There is a growing threat from pressure for bio-fuels such as methanol from northern forests and increasing calls for burning wood for electricity generation. While forestry practices had large impacts on the Great Lakes historically, practices have improved to such an extent that impacts on Lake Huron are generally localized. The relative impacts of NPS pollution from forestry are much lower than those caused by incompatible urban and rural development and agriculture (Bredin 2002). This is generally reflected in differences in nutrient and sedimentation issues between the northern and southern portions of the basin.

Finally, though they were not comprehensively addressed in the NPS conceptual model, it was recognized that there are a number of "emerging chemical issues" for which there is an indication that we may be underestimating their impacts on aquatic ecosystems and communities. These chemicals include pesticides, pharmaceuticals, hormones, and other organic contaminants (Kolpin et al. 2002). While these chemicals are clearly having some impacts (Jobling et al. 1998, Hayes et al. 2003, Blazer et al. 2007), there is currently a paucity of information on the extent of the problem, both in terms of distribution of areas with significant concentrations and the ecological/biological impacts. Much work is needed in the Great Lakes before determining the relative influence and contributing factors for these emerging chemical issues.

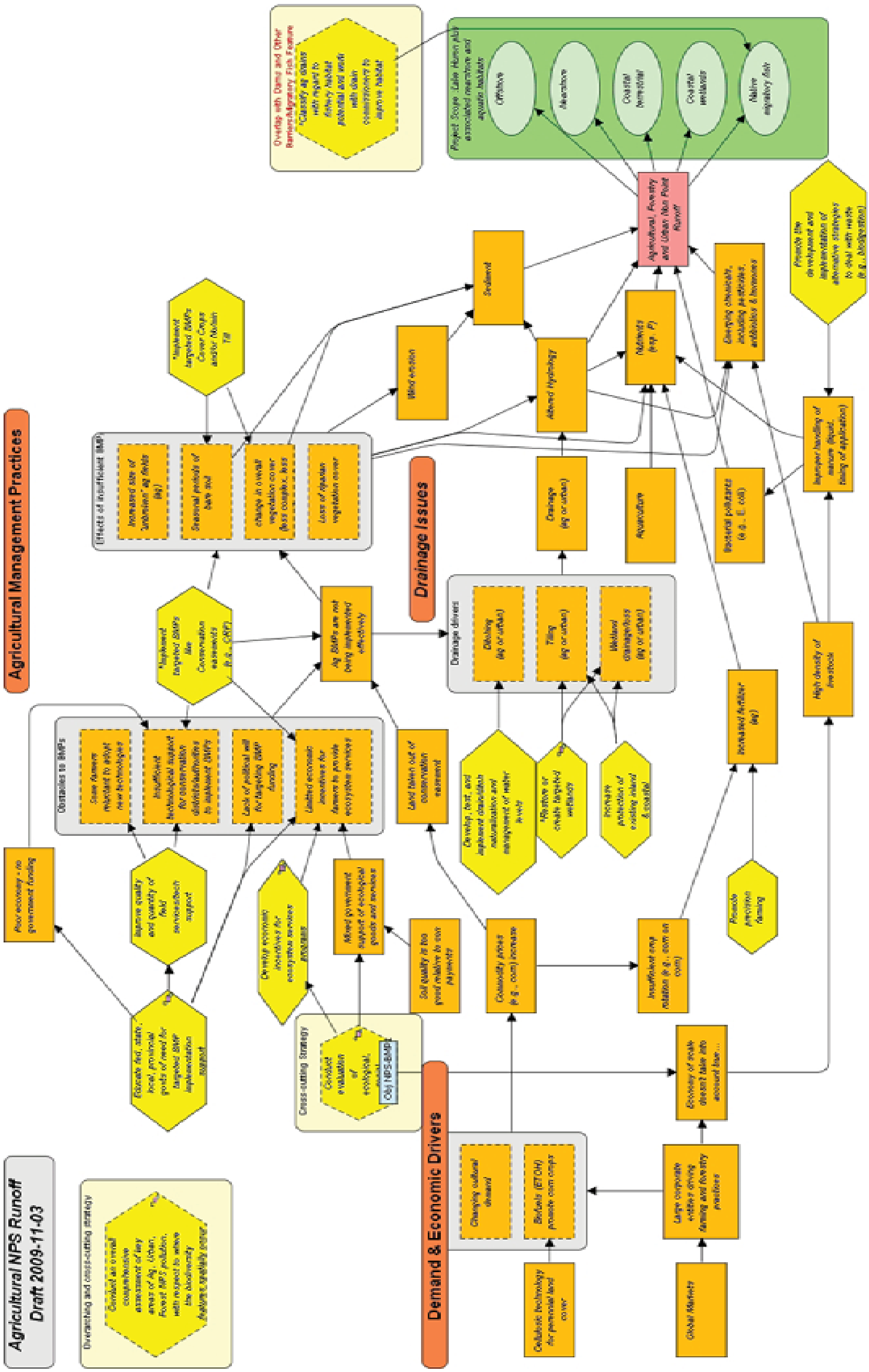

Figure 23: Conceptual model for the threat of agricultural non-point source pollution.

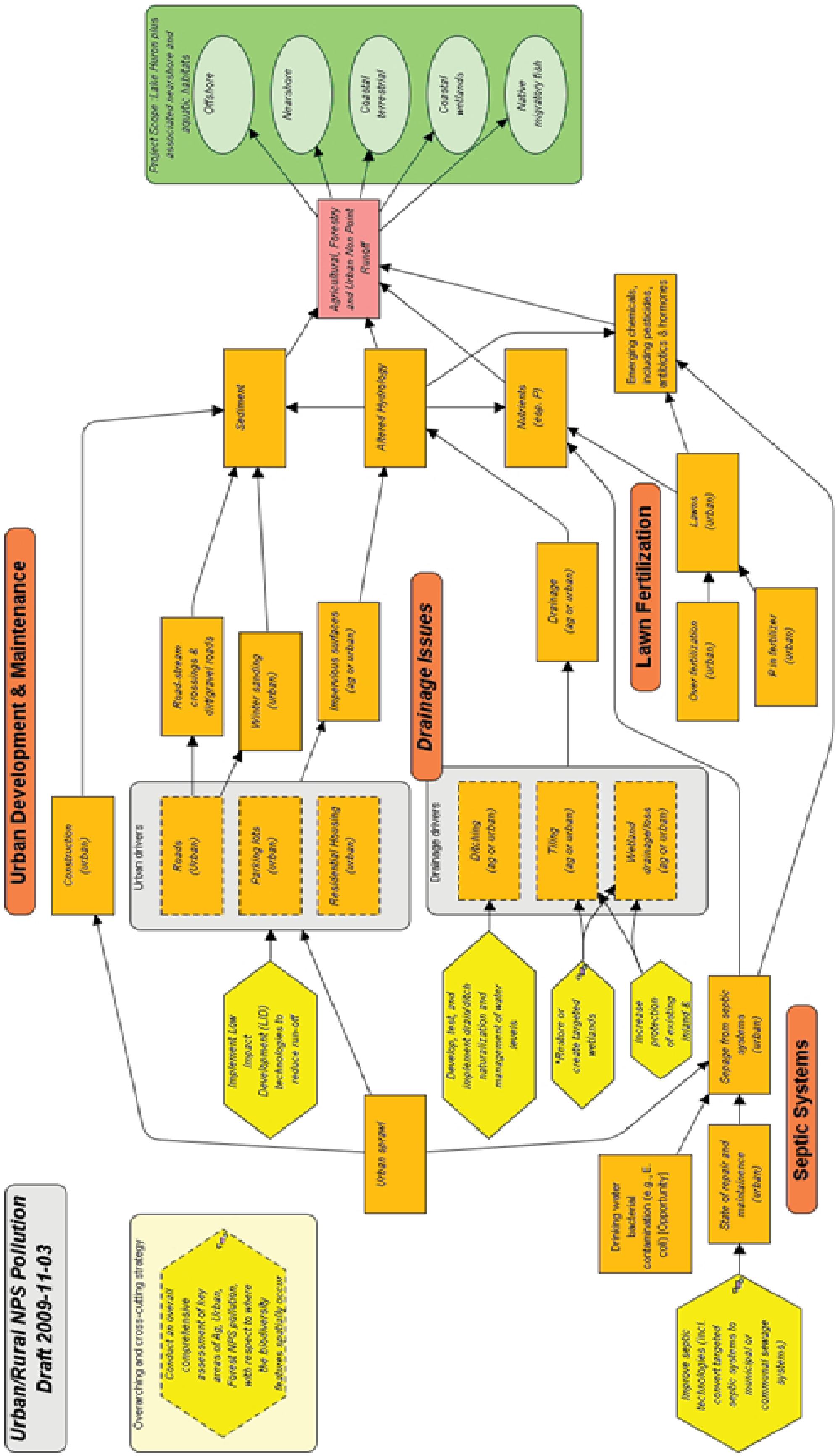

Figure 24: Conceptual model for the threat of urban and rural non-point source pollution.

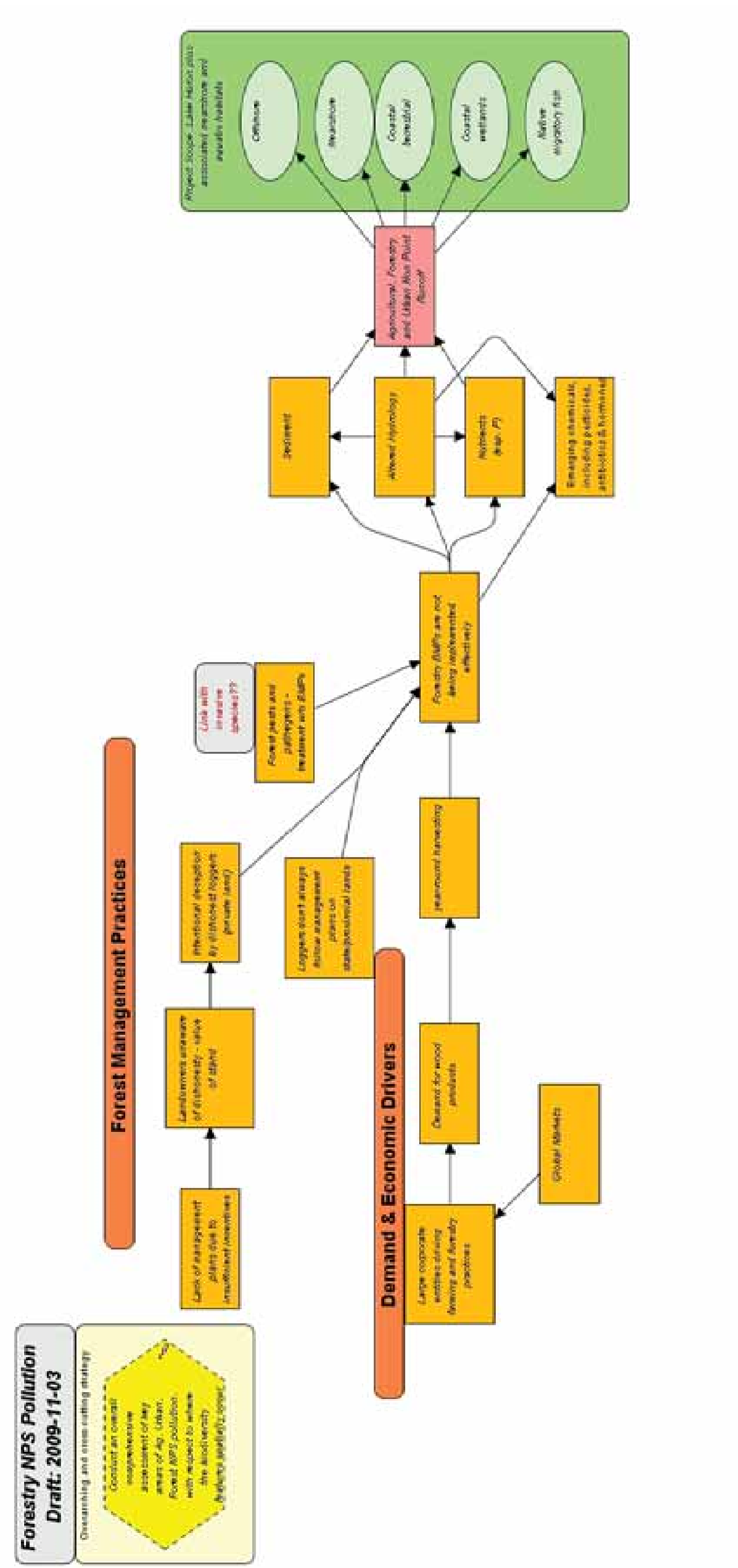

Figure 25: Conceptual model for the threat of forestry non-point source pollution.

6. STRATEGIES

6.1 Methodology[5]

Using the conceptual models developed in Workshop II, working groups identified and developed strategies intended to mitigate the direct and indirect threats and/or alleviate some of the pressures or conditions (i.e. drivers) that perpetuate them. Participants were provided documents outlining strategies developed from other planning efforts across the basin to aid in brainstorming strategies. Strategies were developed to address the impacts of key threats (see Chapter 5) on Lake Huron's biodiversity features (Chapter 3). Subsequently, we selected 21Priority Conservation Strategies based upon an assessment of potential impact and feasibility.

> **Potential impact:** The degree to which the strategy (if implemented) will lead to desired changes in the situation at your project site.
>
> **Feasibility:** The degree to which the strategy could be implemented within a likely time frame, given financial, staffing, ethical, and other constraints.

The Core Working Team summarized the strategies developed in Workshop II and conducted a review of strategies identified in other lake basin planning efforts (as cited above). A number of related, basin-wide reports and plans were consulted to reaffirm expert-identified strategies and to identify any gaps; these documents include:

- Lake Huron Binational Partnership Action Plans (LHBP 2004, 2006, and 2008);
- Lake Huron Initiative Action Plan (Bredin 2002);
- Great Lakes Fishery Commission's Environmental Objectives for Lake Huron (Liskauskas et al. 2007);
- Great Lakes Fishery Commission's Lake Huron Fish-Community Objectives (DesJardine et al. 1995); and,
- NCC's Ecosystem Status and Trends: Draft Great Lakes Report – Lake Huron Chapter (NCC 2009).

Additional cross-referencing was done with the Great Lakes Regional Collaboration Strategy (GLRC 2005) to ensure consistency with region-wide recommendations, as well as the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009) for consistency with other Great Lakes strategic documents. Although reviewing more local and regional references was not always possible, a number of key sources were recommended during regional workshops and, as appropriate, are mentioned below in the 'Recommended Scale and Opportunity Action Areas for Implementation' sections of each detailed strategy. Additional strategies identified through this review process were added to the conceptual models and working lists of draft strategies for each threat.

The updated draft strategies were then peer-reviewed by LHBCS participants through web conferences and at Workshop III. During Workshop III, participants decided which strategies were most feasible ***within the next five years (2011-2015)***, based on their knowledge of efforts underway and other circumstances that may positively or negatively influence implementation. These strategies were then further detailed by developing one or more time-bound objectives and supporting strategic actions. Regional workshops were conducted to

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[5] NOTE: Additional information about the strategy development process can be found in the following report sections: the Threats Chapter contains conceptual models; the Next Steps Chapter contains results chains as potential tools for implementation and monitoring; the "Stakeholder and Partner Input into Strategy" section in the CAP Process Chapter further describes the workshop process.

receive input from local stakeholders on how these strategies might link to ongoing efforts, and helped identify opportunity areas for implementation. Note that, due to the nature of how this information was collected and the breadth of material covered during the regional workshops, the opportunity areas for implementation identified below do not represent an exhaustive list of all potential implementation locations. In some cases, the level of detail on Canadian opportunity areas was greater due to additional time available to gather this input during those workshops; this is not to suggest those strategies only have applicable opportunities in Canada. The projects and places listed in the opportunity areas for implementation section are good examples of points of collaboration and initiation of these strategies, but are a subset of the opportunities for implementation around the Lake Huron basin.

6.2 Summary

We selected 21 Priority Conservation Strategies that were determined by workshop participants to be most feasible and important to implement within the next 5 years based on stakeholder knowledge of efforts underway and other circumstances that may positively or negatively influence implementation (Table 18). They are presented in the following table, organized by broad categories for conservation action, which were modified from the International Union for Conservation of Nature-Conservation Measures Partnership (IUCN-CMP) classification (Salafsky et al. 2008). Several strategies are applicable to more than one threat. The scale for implementation ranges from Great Lakes basin-wide, to specific to Lake Huron, and regional or local in application. Following this summary table, in Section 6.3, we provide a detailed description of each strategy with associated objectives, strategic actions, related strategies, recommended scale for implementation, and opportunity areas for implementation. A full list of Conservation Strategies developed during the Lake Huron Biodiversity Conservation Planning process is presented in Appendix D.

Table 18: Priority conservation strategies for action on five-year timeframe (2011-2015).

Strategy		Threat(s) Abated	Scale of Implementation
1. Land and Water Protection Strategies			
Strategy 1.1	Effectively conserve a system of public and private conservation lands for Coastal Terrestrial System and Nearshore Zone features that are resilient to changes in land use and climate.	Climate Change; Housing and Urban Development and Shoreline Alteration	Regional/Local
2. Land and Water Management Strategies			
Strategy 2.1	Implement an integrative approach to barrier management that accounts for ecological and social values.	Dams and Other Barriers	Lake Huron Basin-wide
Strategy 2.2	Implement improved septic technologies, including conversion of targeted septic systems to municipal or communal sewage systems.	Non-point Source Pollution	Lake Huron Basin-wide
Strategy 2.3	Implement targeted agricultural best management practices (BMPs) to address non-point source pollution impacts to Lake Huron biodiversity.	Non-point Source Pollution	Regional/Local

Strategy		Threat(s) Abated	Scale of Implementation
Strategy 2.4	Develop and implement an integrative, adaptive, and harmonized framework for coastal management within selected US and Canadian geographic regions.	Housing and Urban Development and Shoreline Alteration	Regional/Local
Strategy 2.5	Restore priority Coastal Terrestrial System and Nearshore Zone features.	Housing and Urban Development and Shoreline Alteration	Regional/Local
Strategy 2.6	Develop and implement programs that identify and conserve priority Nearshore Zone and Coastal Terrestrial System habitats.	Housing and Urban Development and Shoreline Alteration	Lake Huron Basin-wide
3. Species Management Strategies			
Strategy 3.1	Restore native populations of Lake Huron's aquatic and terrestrial species.	Non-native Invasive Species	Regional/Local
4. Education and Awareness Strategies			
Strategy 4.1	Enhance knowledge, technical skills and information exchange to build capacity of local policy and land use planning authorities to include biodiversity values into their decisions.	Housing and Urban Development and Shoreline Alteration	Regional/Local
Strategy 4.2	Better educate the public on climate change issues: by creating credibility and a sense of urgency for climate change mitigation strategies being implemented across the basin, and by providing information about observed and expected climate changes affects in Lake Huron that is easily understood.	Climate change	Great Lakes Basin-wide
Strategy 4.3	Increase community engagement, awareness, understanding, and commitment to Coastal Terrestrial System and Nearshore Zone conservation.	Housing and Urban Development and Shoreline Alteration	Regional/Local
5. Law and Policy Strategies			
Strategy 5.1	Eliminate ballast water as a vector for invasive species introductions.	Non-native Invasive Species	Great Lakes Basin-wide
6. Livelihood, economic and other Incentives Strategies			
Strategy 6.1	Develop economic incentives for ecosystem services programs.	Non-point Source Pollution	Lake Huron Basin-wide

Strategy		Threat(s) Abated	Scale of Implementation
7. External Capacity Building Strategies			
Strategy 7.1	Develop and implement a data and knowledge management system designed to guide future conservation actions and effectively track implementation efforts.	All	Great Lakes Basin-wide
Strategy 7.2	Form a SWAT Team to eradicate new invasive species before establishment/naturalization.	Non-native Invasive Species	Lake Huron Basin-wide
8. Research Strategies			
Strategy 8.1	Establish a system for monitoring biodiversity and climate change in sentinel watershed sites.	Climate Change	Great Lakes Basin-wide
Strategy 8.2	Assess the value of ecological goods and services provided by Lake Huron, including how values are altered under climate change scenarios.	Housing and Urban Development and Shoreline Alteration; Non-point Source Pollution; Climate Change	Great Lakes Basin-wide
Strategy 8.3	Develop a Lake Huron-wide risk assessment that informs strategies for the prevention of invasive species.	Non-native Invasive Species	Lake Huron Basin-wide
Strategy 8.4	Conduct place-based research and development of control techniques non-native invasive species.	Non-native Invasive Species	Regional/Local
Strategy 8.5	Conduct a comprehensive assessment of key action areas for mitigation of agriculture, urban, and forest non-point source pollution, with special regard for areas important to biodiversity features and areas where climate change is anticipated to exacerbate current problems.	Non-point Source Pollution; Climate Change	Lake Huron Basin-wide
Strategy 8.6	Enhance research and monitoring of the Nearshore Zone and Coastal Terrestrial System margin.	Housing and Urban Development and Shoreline Alteration	Great Lakes Basin-wide

NOTE: Additional information about the strategy development process can be found in the following report sections: the Threats Chapter contains conceptual models; the Next Steps Chapter contains results chains as potential tools for implementation and monitoring; the "Stakeholder and Partner Input into Strategy" section in the CAP Process Chapter further describes the work conducted during the workshops.

6.3 Priority Strategy Details

The following section describes each of the 21 Priority Conservation Strategies, along with their associated objectives, strategic actions, complementary strategies (those that were identified, but not detailed as among the most feasible), and scale and, where known, specific opportunities for implementation. For each strategy category, the section concludes with the list of other supporting or complementary strategies identified but not fully developed due to expert-determined lower feasibility. In some cases, similar strategies were developed in multiple threat-based working groups; the Core Working Team combined some strategies to eliminate redundancy in the Technical Report and to foster efficiencies in implementation. For a complete table with all strategies identified during the LHBCS process, see Appendix D.

1. Land and Water Protection Strategies

Land and water protection by governmental and non-governmental entities represent a core strategy necessary to achieve conservation of the Lake Huron basin. Land and water protection in the Lake Huron basin has been highly successful, but will become more important as the threats to Lake Huron become more pervasive over time. Below we highlight a land and water protection strategy designed to implement.

Strategy 1.1	Effectively conserve a system of public and private conservation lands for Coastal Terrestrial System and Nearshore Zone features that are resilient to changes in land use and climate.
Objectives: 1. Identify priority areas, incorporate into guidance documents, and initiate protection of lands that are predicted to be important for maintaining the viability of Lake Huron biodiversity and provision of ecosystem services under changes in land use, human population growth and climate change scenarios. 2. Lake Huron Binational Partnership Action Plan has endorsed or incorporated the pr0otected area priorities outlined in the Lake Huron Biodiversity Conservation Strategy.	
Strategic Actions: • Conduct inventory of existing habitats. • Collect and utilize bathymetry data to facilitate credible modeling of anticipated land use and climate change impacts in coastal and Nearshore Zone systems. • Conduct modeling of predicted changes in shoreline and coastal habitat and watersheds due to land use and climate change. • Based on modeling results, identify a network of priority areas to conserve. • Identify sensitive in-lake habitats and devise appropriate strategies, which may include National Marine Conservation Areas, freshwater protected areas, special management or permitting requirements, or other protection mechanisms. ▪ Revisit the Great Lakes Heritage Coast or similar initiatives that proposed a protected coastal corridor and determine feasibility for selected Lake Huron regions. ▪ Promote and engage multiple partners in Coastal and Marine Spatial Planning.	
Related Strategies: • Strategy 1.2 – Effectively conserve critical wetlands, Coastal Terrestrial Systems and Islands predicted to remain viable under climate change and enhance viability. • Strategy 1.3 – Conserve priority coastal habitats that are unprotected and vulnerable to loss	

and degradation. • Strategy 1.4 – Identify priority Coastal Terrestrial System and Nearshore Zone habitats that are unprotected and vulnerable to loss and degradation. • Strategy 2.6 – Develop and implement programs that delineate, evaluate and designate sensitive areas for protection.
Recommended Scale for Implementation: • Regional/Local.
Opportunity Areas for Implementation: • Land and water protection is warranted throughout the Lake Huron basin.

2. Land and Water Management Strategies

Conservation goals cannot be achieved with direct land and water protection alone. Therefore, strategies that address the conservation across all lands and waters, whether managed for biodiversity or resource production outcomes, are essential. Below, we provide a suite of strategies directed at achieving conservation goals on working lands and waters.

Strategy 2.1	Implement an integrative approach to barrier management that accounts for ecological and social values.
Objectives: 1. The Lake Huron Binational Partnership Action Plan includes the development of a Tributary Connectivity Management Plan as a priority. 2. A Tributary Connectivity Management Plan is completed for Lake Huron. This plan considers biodiversity conservation, lakewide objectives for fisheries and aquatic biodiversity, invasive species, sediment and chemical cycling, and other values, as well as stating explicitly which values take precedence in each tributary with relevant recommendations for dam/barrier management based on the priority values.	
Strategic Actions: • Complete spatially-explicit dataset of dams and barriers in the Ontario portion of the Lake Huron basin and compile all information in an accessible international GIS data layer. • Complete consistent attributes for barrier inventory, including management objectives where possible. • Review watershed plans, lakewide objectives, and other non-natural resource plans (e.g., micro-hydro). • Map habitat use for key species, including Coastal Wetlands and Nearshore Zone areas, while considering potential changes in climate. • Assess risk of aquatic biodiversity viability due to climate changes. • Select priority tributaries to develop management objectives. These ranking could include: sea lamprey production, key species, species at risk (including rare, vulnerable, or listed species), upstream habitat quality, and competing stream uses). • Develop draft management objectives for each priority tributary. This would include: fish, sediment, and other values, as well as recommendations for dams/barrier management (e.g. maintain, remove, modify, allow new, prevent, etc.) and cost/benefit analysis that makes trade-offs explicit.	

- Create opportunities for public comment on draft management objectives through the Lake Huron Binational Partnership.
- Finalize objectives and management plan, adapting as needed.

Related Strategies:

- Strategy 2.11 – Restore aquatic and terrestrial connectivity related to dams and barriers and shoreline development in light of climate change impacts.
- Strategy 2.13 – Minimize impacts from new dams and barriers.
- Strategy 2.14 – Prevent new impassible dams and barriers.
- Strategy 2.15 – Manage dams to mimic natural flow processes.
- Strategy 2.16 – Install alternative, or modify existing structures (including poorly designed or maintained culverts), to allow for ecological connectivity, restored chemical cycling, and sediment flow.
- Strategy 2.17 – Remove critical dams where appropriate.

Recommended Scale for Implementation:

- Lake Huron Basin-wide

Opportunity Areas for Implementation:

Canada

- Hanover Dam was flagged as a potential removal opportunity.
- Walkerton Dam on the Saugeen River is being managed to maintain fish passage; other dams on the Saugeen, including the Maple Hill Dam, may represent removal opportunities.
- A new fishway was installed at Thornbury Dam on the Beaver River.
- Several dams have recently been removed or are slated for removal on the Nottawasaga River.
- The Ontario Ministry of Natural Resources is conducting habitat modeling and species use in stream segments that could be made accessible through dam/barrier removal or modification (e.g. Niagara Escarpment Stream Monitoring [NETSMART] and Southern Ontario Stream Monitoring [SOSMART]).

United States

- Public Sector Consultants, Inc. has conducted an inventory and prioritization of dam removal on the Saginaw River; removal of the Chesaning Dam and installation of a rock ramp has helped generate public interest in further dam removal; abating the threat on the Saginaw River and its tributaries is the highest priority and opportunity in Saginaw Bay.
- Huron Pines is inventorying and mapping small dams on small coastal reaches on Michigan's Northeast Lower Peninsula lakeplain where owners are putting in small dams to create ponds.
- Central Michigan University researchers are inventorying culverts in the Lower Peninsula of Michigan and working on assessing barriers to ecological connectivity.
- The Nature Conservancy is mapping and modeling potential habitat that could be improved and made accessible through dam/barrier modification or removal.

NOTE: while implementing an integrated approach to barrier management is the goal of this strategy, experts commented opportunistic dam/barrier removal and retrofitting could build necessary expertise and political will for this work; thus, some place-based opportunities are noted, even in advance of development of the desired integrated approach.

Strategy 2.2	Implement improved septic technologies, including conversion of targeted septic systems to municipal or communal sewage systems.

Objectives:

1. Identify areas with most problematic septic contributions.
2. Address several high priority areas through municipal tie-in or communal systems.

Strategic Actions:

- Develop a map of septic systems in problematic areas.
- Compile and identify priority biodiversity areas.
- Expand septic system inspection frequency, potentially utilizing mandates requiring inspection at point-of-sale, with change in use, or at time of maintenance.
- Create a coalition to coordinate septic management.
- Develop incentives programs for alternative technologies.
- Where possible, tie priority problem septic systems into municipal or communal systems.
- Promote incentive programs to update septic systems in important biodiversity areas where municipal or communal systems are not possible and for use of septic best practices (e.g. placing further from water bodies).

Related Strategies:

- Strategy 2.2 – Implement improved septic technologies, including conversion of targeted septic systems to municipal or communal sewage systems.
- Strategy 2.5 – Restore targeted Coastal Terrestrial System and Nearshore Zone features.
- Strategy 2.11 – Restore aquatic and terrestrial connectivity related to dams and barriers and shoreline development in light of climate change impacts.
- Strategy 2.27 – Restore or create targeted inland wetlands.
- Strategy 2.29 – Implement Low Impact Development (LID) technologies to reduce run-off.
- Strategy 2.31 – Educate federal, state and local provincial governments on the need for targeted best management practice implementation support.
- Strategy 2.33 – Promote the development and implementation of alternative strategies to deal with waste (e.g., biodigestion).
- Strategy 8.5 – Conduct a comprehensive assessment of key action areas for mitigation of agriculture, urban, and forest non-point source pollution, with special regard for areas important to biodiversity features and areas where climate change is anticipated to exacerbate current problems.

Recommended Scale for Implementation:

- Analysis – Lake Huron Basin-wide.
- Implementation – Regional/Local.

Opportunity Areas for Implementation:

Canada

- There is currently funding in several coastal areas along Lake Huron to upgrade septic systems in Ontario (e.g., Grey/Saugeen Source Water Protection Area) and this is under consideration in Michigan.
- Pine River Watershed Initiative Network

United States

- Huron County, Michigan has a proposed by-law regarding septic systems.
- County health departments generally have significant data and knowledge for identifying priority areas, though these data are not always available and does not always result in identification of priorities at a larger scale.

Strategy 2.3	Implement targeted agricultural best management practices (BMPs) to address non-point source pollution impacts to Lake Huron biodiversity.

Objectives:

1. A nested suite of prioritized areas for agricultural BMP promotion have been identified.
2. At least half of the resources for agriculture BMP implementation in the Basin are targeted.
3. A 25% reduction (by 2020) in average Nearshore Zone phosphorus concentrations from 1995-2005 levels.
4. Funding for research (e.g. NRCS CEAP) on benefits of targeted BMPs continues at 2009 levels.

Strategic Actions:

- Implement targeted BMPs, including planting of cover crops, no- (or minimal-)till, conservation easements, riparian buffers, and promotion of precision farming.
- Ensure that technical support is sufficient to effectively target BMPs in priority areas.
- Improve knowledge of the benefits of BMPs for both farmers and society.
- Utilize alternative economic incentives (see Strategy #3) to maximize BMP implementation in priority areas.
- Conduct strategic monitoring to determine BMP effectiveness (especially as it relates to climate changes scenarios) and utilize this information to promote most effective practices within targeted areas and to develop performance measures.
- Utilize the priority areas for targeted BMPs identified in Objective #1 and identify mechanisms to target resources.
- Educate policymakers of the need to use public funding sources for targeting BMPs.
- Identify information gaps in BMP effectiveness.
- Identify or develop funding mechanism to test BMP effectiveness.
- Conservation groups coordinate to proactively promote BMPs and provide information to farmers on the economic, social, and environmental value of implementing BMPs.
- Provide similar information to the general public so that they understand the environmental benefits that farmers have the potential to provide.

Related Strategies:

- Strategy 2.4 – Develop comprehensive coastal management initiatives at U.S. and Canadian pilot sites.
- Strategy 2.7 – Mitigate human responses to climate change in coastal areas (e.g., shoreline structures and shoreline development).
- Strategy 2.8 – Address non-point source pollution potentially exacerbated by climate change.
- Strategy 2.9 – Design precautionary fisheries policy and management strategies to account for anticipated population changes based on climate change impacts
- Strategy 2.26 – Improve road-stream crossings to reduce sedimentation.
- Strategy 2.34 - Classify agricultural drains with regard to fishery habitat potential and work with drain commissioners to improve habitat.
- Strategy 4.2 – Public engagement in creating a "climate for change" – provide additional credibility and sense of urgency for climate change mitigation strategies implemented by others in the Great Lakes and beyond by providing information about observed and expected climate change impacts in Lake Huron.

Recommended Scale for Implementation:

- Regional/Local in Agriculturally dominated regions (see Figure 22).

Opportunity Areas for Implementation:

Canada

- There is substantial funding available through the Canada-Ontario Farm Plan Program and US Department of Agriculture (USDA) Farm Bill program that can be targeted to priority areas.
- The Canada-Ontario Farm Plan Program and several USDA Farm Bill programs require the development of Environmental Farm Plans (EFPs) or conservation plans.
- There may be potential for revision in the Canadian drain code to require drainage BMPs, but there is little short-term potential for this in Michigan.
- Utilize information on priority road-stream crossing to reduce channel erosion from plans developed by the Ontario Natural Heritage Information Centre, watershed groups, conservation districts, or conservation authorities.
- Ontario Ministry of Agriculture, Food and Rural Affairs provided modest funding (09-10 dollars) to all watersheds from Southampton to Sarnia for agricultural BMPs.
- The Alternative Land Use Services (ALUS) and Payment for Ecological Good and Services (PEGS; http://www.cielap.org/pdf/HuronCounty_KateMonk.pdf) programs were developed to promote public investment in compensating farmers for the ecological services they provide when they implement BMPs.

United States

- A resource inventory is being completed for the Pigeon and Pinnebog River watersheds and Huron County has received substantial funding to reduce sediment and nutrient pollution loadings and e. coli contributions from the Pigeon and Pinnebog Rivers to Saginaw Bay. While small, these watersheds have high relative contributions of NPS pollutants.
- In some areas, there is growing concern about potential reduced yield due to over-drainage of lands; this may provide an opportunity to remove some drainage infrastructure or to document losses in yield with excessive drainage.
- The Conservation Reserve and Enhancement Program (CREP) was targeted to Saginaw Bay.
- There may be potential to engage with the BMP Challenge (http://www.bmpchallenge.org/) in some intensive agricultural areas such as Saginaw Bay.
- Saginaw Bay WIN has funded farmer risk-protection program to encourage farmers to implement BMPs on a trial basis, with the anticipation that it will result in long-term adoption.
- Utilize the Michigan Department of Natural Resources and Environment functional wetland assessment in wetland BMP prioritization.

Strategy 2.4	Develop and implement an integrative, adaptive, and harmonized framework for coastal management within selected US and Canadian geographic regions.

Objectives:

1. The Lake Huron Binational Partnership agrees on an overarching vision, goals, and objectives for a harmonized and adaptive coastal and Nearshore Zone management framework that integrates the interests of the public and management agencies, resilient biological and physical processes and pathways, and the protection of habitat, native species, and communities.
2. Obtain agreement, financial support, and participation that incorporate multiple agencies, jurisdictions and community interests in preventing detrimental effects of unsustainable

coastal development and Nearshore Zone alteration and conserving bio-physical processes and features.

3. Within each selected region, identify stakeholders and obtain buy-in from local, provincial, state and federal partners on the framework, project scope, vision, goals, objectives, and strategies.
4. Ensure that science-based coastal management plans and strategies are integrated and adopted in Municipal Official Plans, Zoning Bylaws and Conservation Authorities Generic "Development, Interference, & Alteration" Regulations and equivalent US policies.

Strategic Actions:

- Establish multi-agency and local stakeholder governance frameworks for Canadian and US coastal management plans that harmonize coastal and Nearshore Zone protection, regulation, enforcement, and policy across multiple jurisdictions.
- Develop a Geographical Information System - Decision Support System (GIS/DSS) to compile, integrate and analyze multiple data sources on the coastal and Nearshore Zone ecosystem to identify the current status, temporal trends, and to project future impacts of development and land-use scenarios.
- Identify current regulatory and policy mechanisms to protect Nearshore Zone and coastal environments, their limitations, barriers, and identify opportunities to strengthen policies, regulations, and conservation.
- Develop and implement a communications strategy targeted at residents, developers, communities, municipalities and government agencies to ensure that natural shoreline processes and pathways are understood, valued and protected.
- Build capacity at local level to ensure information availability, education, training, and sustainable funding for agencies responsible for shoreline planning and protection.
- Establish an integrated management governance mechanism at selected regions based on the cooperation of all decision makers, users and civil society in planning and managing activities and uses of coastal and Nearshore Zone resources from a sustainable development perspective. Take into account the coastal/nearshore ecosystem's carrying capacity, the integrated management of activities and programs, and participation of users, civil society and municipalities in decision-making and activities affecting Lake Huron.
- Develop and implement science-based, integrated, and adaptive coastal management strategies at selected US and Canadian regions and monitor project outcomes, evaluate results, document, adapt, and share results and learning experiences.
- Consider a moratorium or interim restrictions on dredging in areas of high impact and ecological sensitivity.
- Establish performance measures and schedule for adaptive management and long term management and coastal management plan implementation.
- Encourage science-based strategies and decisions that link watershed land uses with coastal and Nearshore Zone conservation needs in US and Canadian watersheds.
- Determine opportunities for tax incentives as a means to conserve Nearshore Zone and coastal habitat.
- Ensure that Lake Huron-wide coastal and Nearshore Zone management strategies and policies are developed to provide an integrated framework for land use planning that considers physical processes and pathways, ecological health, and habitat and native species protection and preservation.
- Consider a Great Lakes Biodiversity Conservation Act and/or Protection Plan that conserves

the physical processes and habitat of the Nearshore Zone and Coastal Terrestrial Systems.

- In Ontario, take advantage of the reviews of the Provincial Policy Statement as an opportunity to strengthen Nearshore Zone and coastal protection such that wording is strengthened to protect Nearshore Zone processes, pathways, functions, and biological species and communities.

Related Strategies:

- Strategy 1.1 – Effectively conserve a system of public and private conservation lands for Coastal Terrestrial System and Nearshore Zone features that are resilient to changes in land use and climate.
- Strategy 2.6 – Develop and implement programs that identify and conserve priority Nearshore Zone and Coastal Terrestrial System habitats.
- Strategy 3.1 – Restore native populations of Lake Huron's aquatic and terrestrial species.
- Strategy 4.1 – Enhance knowledge, technical skills and information exchange to build capacity of local policy and land use planning authorities to include biodiversity values into their decisions.
- Strategy 4.2 – Better educate the public on climate change issues: by creating credibility and a sense of urgency for climate change mitigation strategies being implemented across the basin, and by providing information about observed and expected climate changes affects in Lake Huron that is easily understood.
- Strategy 4.3 – Increase community engagement, awareness, understanding, and commitment to Coastal Terrestrial System and Nearshore Zone conservation.
- Strategy 7.1 – Develop and implement a data and knowledge management system designed to guide future conservation actions and effectively track implementation efforts.
- Strategy 8.1 – Establish a system for monitoring biodiversity and climate change in sentinel watershed sites.
- Strategy 8.2 – Assess the value of ecological goods and services provided by Lake Huron, including how values are altered under climate change scenarios.
- Strategy 8.4 – Conduct place-based research and development of control techniques non-native invasive species.
- Strategy 8.6 – Enhance research and monitoring of the Nearshore Zone and Coastal Terrestrial System margin.

Recommended Scale for Implementation:

- Regional/Local.

Opportunity Areas for Implementation:

Canada

- The following locations were mentioned as possible pilot sites/beneficiaries to this type of management:
- Southern Georgian Bay from Tobermory to Port Severn
- Southeast Shores – Tobermory to Sarnia
- Ipperwash (dynamic beach, development pressure, absence of shoreline management plan)
- Bluffs at Grand Bend to Amberly

- Northeast Shore: Provide support for developing and implementing a Northern Georgian Bay - Coordinated Wetlands Strategy.

United States

- TBD - not identified during regional workshops.

Strategy 2.5	Restore priority Coastal Terrestrial System and Nearshore Zone features.

Objective:

1. Identify and pursue opportunities for Coastal Terrestrial System and Nearshore Zone aquatic habitat rehabilitation with involvement from local stakeholders.
2. Community-based initiatives that address biodiversity conservation are supported by all levels of government.
3. Programs that create and rehabilitate/restore coastal wetland habitat for fish and marsh-nesting birds are continued and augmented where needs are greatest.

Strategic Actions:

- Identify priority sites to re-establish connectivity, natural variations in water temperatures, water quality, and natural hydrological flow regimes, to maximize spawning/breeding, nursery, and feeding habitats of fish and wildlife.
- Identify limiting factors, evaluate opportunities, and propose actions to rehabilitate and enhance coastal and Nearshore Zone habitats and their ecological integrity;
- Develop performance measures to evaluate rehabilitation efforts taking into account changes in land use, shoreline alteration trends, regulation, policy, and climate change.
- Celebrate and publish success stories of community conservation and stewardship initiatives.
- Make engineering techniques available to the general public, municipalities, and counties that maintain and/or enhance natural processes and pathways.
- Encourage management agencies to incorporate aquatic habitat improvements and sediment and water quality as part of their planning process.
- Evaluate, fund, and implement the placed-based restoration opportunities.
- Complete a synopsis of existing biological and physical conditions and processes, cultural influences and coastal/nearshore communities in selected watersheds.
- Complete a compendium of aquatic habitat restoration techniques detailing where they are appropriate for use, their advantages and disadvantages, and their costs.
- Build on existing rehabilitation strategies such as the Toronto Waterfront Natural Heritage Program-Aquatic Habitat Restoration Strategy.
- Support existing rehabilitation plans (e.g., Manitoulin Island-Wide Stream Rehabilitation Strategic Plan) which include strategies and implementation efforts at the confluence of the lake and its tributaries.
- To guide the development of Strategy 2.5, an Advisory Committee will develop a set of guiding principles and site selection criteria. The strategy should incorporate the ecosystem approach, ecological integrity, self-sustaining communities, ecological connectivity, conservation design, native species, human uses of the shoreline and Nearshore Zone waters, consultation and consensus. The strategy should also incorporate priority rehabilitation sites listed in other strategies such as the Lake Huron Environmental Objectives.

Related Strategies:

- Strategy 2.1 – Implement an integrative approach to barrier management that accounts for

ecological and social values. • Strategy 2.3 – Implement targeted agricultural best management practices (BMPs) to address non-point source pollution impacts to Lake Huron biodiversity. • Strategy 2.4 – Develop and implement an integrative, adaptive, and harmonized framework for coastal management within selected US and Canadian geographic regions. • Strategy 3.1 – Restore native populations of Lake Huron's aquatic and terrestrial species. • Strategy 8.5 – Conduct a comprehensive assessment of key action areas for mitigation of agriculture, urban, and forest non-point source pollution, with special regard for areas important to biodiversity features and areas where climate change is anticipated to exacerbate current problems.
Recommended Scale for Implementation: • Regional/Local.
Opportunity Areas for Implementation: Canada Southern Georgian Bay: 1. Silver Creek Wetlands Restoration 2. Carter Bay on Manitoulin Island North Shore: • Needs and opportunities exist within the tributaries such as Manitou River, Blue Jay Creek, Mindemoya River, and Kagawong River. • Re-establish the loss of connectivity, altered stream temperatures, water quality, and hydrological flow regimes to maximize the spawning, nursery and feeding habitats in the Garden River, Mississagi River and Spanish River for walleye and lake sturgeon. Northeast Shore: ▪ Conduct walleye spawning bed enhancement work at candidate sites in East Georgian Bay: Baxter Lake outlet; McCrae Lake outlet; Musquash River; northeast Georgian Bay site. • Re-establish the loss of connectivity, altered stream temperatures, water quality, and hydrological flow regimes to maximize the spawning, nursery and feeding habitats in the Moon River (walleye, sturgeon, muskellunge), Severn River (walleye, sturgeon, muskellunge) and Nottawasaga River (walleyes, sturgeon, rainbow trout). Southeast Shore 3. Address dune ecosystem degradation at 18 mile ANSI north of Goderich. 4. Restore shorelines, possibly by using clean dredge materials to nourish beaches, to overcome down-current sand starving of beaches due to alterations at Goderich shoreline. United States • TBD - not identified during regional workshops.

Strategy 2.6	Develop and implement programs that identify and conserve priority Nearshore Zone and Coastal Terrestrial System habitats.

Objectives:

1. Conservation plans are developed for unprotected and vulnerable habitat in need of conservation action.
2. In Ontario, at least 30 Coastal Wetlands are evaluated, designated as Provincially Significant Wetlands, and acknowledged through official land use plans.

Strategic Actions:

- Establish a Lake Huron Biodiversity Conservation Technical Working Group to identify criteria, opportunities, and plans for biodiversity conservation.
- Develop criteria for prioritizing unprotected habitats that integrates ecological (species movement, gene flow, and key ecosystem processes), social, and economic principles and needs.
- Assess current conservation status through a GAP analysis to determine current degree of protection among significant coastal habitat types.
- Cultivate local constituency and consistent program support to ensure delineation, evaluation, and provincial designation for the protection of significant Coastal Wetlands and Coastal Terrestrial System habitat through land use planning.
- Continue to conduct assessments to aid in prioritizing sensitive areas using existing mechanisms such as Environmentally Significant Areas (ESAs), Provincially Significant Wetlands (PSWs), and Areas of Natural and Scientific Interest (ANSI) in Ontario and natural features inventories in Michigan.
- Develop and implement a comprehensive coastal/nearshore acquisition strategy to secure unprotected and vulnerable wetlands, tributary mouths and floodplains, Coastal Terrestrial System and Nearshore Zone, and key buffer zones.
- Identify priority uplands that need to be protected so they can serve as ecological buffers to coastal habitats, including wetlands, tributary floodplains, and mouths.
- Consider development, administration, and implementation of a protected natural coastal corridor including core natural areas, buffer zones, and coastal transition zones on newly exposed lands.

Related Strategies:

- Strategy 1.2 – Effectively conserve critical wetlands, Coastal Terrestrial Systems and Islands predicted to remain viable under climate change and enhance viability.
- Strategy 1.6 – Increase protection of existing inland wetlands.
- Strategy 1.5 – Zone and protect priority/sensitive areas.
- Strategy 2.4 – Develop and implement an integrative, adaptive, and harmonized framework for coastal management within selected US and Canadian geographic regions.
- Strategy 2.5 – Restore priority Coastal Terrestrial System and Nearshore Zone features.

Recommended Scale for Implementation:

- Lake Huron Basin-wide, prioritization may be at the Regional-scale.

Opportunity Areas for Implementation:

Canada

Southern Georgian Bay

- Silver Creek Wetlands

Western Bruce Peninsula and Southeast Shore

- Protect bluffs at Grand Bend to Amberley
- Investigate Oliphant coastal area & Fishing Islands: susceptible to sustained low water levels, development and recreational impact. LHCCC has completed a stewardship plan.
- Identify criteria for buffering in the coastal region that would help to maintain the integrity of Nearshore Zone habitat e.g. wetlands (e.g. is 120 meters sufficient?)

Eastern Georgian Bay and North Channel

- Implement a collaborative Coastal Wetlands conservation strategy for Georgian Bay to address wetland delineation, evaluation, protection, and streamlining policy development and practice amongst multiple jurisdictions with development of a Geographical Information System - Decision Support System (GIS/DSS).
- As part of Eastern Georgian Bay coastal wetland conservation, work with multiple organizations to ensure a coordinated approach to complete 10 wetland evaluations over 2010-2012. Wetland evaluation priority includes Maceys Bay, Baxter Lake, Gloucester Pool (Baxter Twp), Big Island, South Go Home Bay, Rabbit Lake (Gibson Twp), Spider/Kingshot (Conger Twp), Richmond Lake (Foley), Shebeshekong River, Shebeshekong Lake (Carling Twp). Project will include review of partner wetland evaluations.

United States

- TBD - not identified during regional workshops.

3. Species Management Strategies

A comprehensive biodiversity conservation strategy must not only address ecological systems and processes, but must also address species management, especially for species that contribute to the health of both people and nature.

Strategy 3.1	Restore native populations of Lake Huron's aquatic and terrestrial species.

Objectives:

1. Opportunities to restore native populations of aquatic and terrestrial species of Lake Huron and its watershed are identified, funded and implemented.

Strategic Actions:

- Secure funding to support application of effective controls of invasive species.
- Secure funding to continue work on restoring native populations.
- Conduct surveys to determine the percent of public understanding and support of the restoration of native populations of aquatic and terrestrial species.
- Identify priority areas, species and/or communities for restoration.
- Determine appropriate restoration techniques.
- Develop partnerships with landowners where appropriate.
- Work with other agencies as appropriate (e.g. Lake managers for fish species/communities; stewardship councils to work with private land owners; etc.)
- Conduct restoration activities.
- Expand decadal colonial bird surveys to include some inland areas that provide habitat for certain waterbirds not restricted to the Great Lakes, such as double-crested cormorant,

Caspian tern, black tern and common tern
Related Strategies: • Strategy 1.3 – Conserve priority coastal habitats that are unprotected and vulnerable to loss and degradation. • Strategy 1.4 – Identify priority Coastal Terrestrial System and Nearshore Zone habitats that are unprotected and vulnerable to loss and degradation. • Strategy 2.1 – Implement an integrative approach to barrier management that accounts for ecological and social values. • Strategy 2.5 – Restore targeted Coastal Terrestrial System and Nearshore Zone features. • Strategy 2.6 – Develop and implement programs that delineate, evaluate and designate sensitive areas for protection. • Strategy 2.15 – Manage dams to mimic natural flow processes. • Strategy 2.16 – Install alternative, or modify existing structures (including poorly designed or maintained culverts), to allow for ecological connectivity, restored chemical cycling, and sediment flow. • Strategy 2.17 – Remove critical dams where appropriate. • Strategy 2.21 – Monitor white-list species and promote native species over non-native species. • Strategy 2.27 – Restore or create targeted inland wetlands. • Strategy 5.1 – Eliminate ballast water as a vector for invasive introductions. • Strategy 5.3 – Strengthen or draft trade policy/regulation for invasive species. • Strategy 8.6 – Enhance research and monitoring of the Nearshore Zone and Coastal Terrestrial System margin.
Recommended Scale for Implementation: • Regional/Local
Opportunity Areas for Implementation: Canada & United States • Re-establish healthy dune ecosystems • Conserve rare ecological communities such as alvars on public lands • Promote existing and, develop new, incentive programs for private land owner participation • Build on existing restoration activities. For example, Spanish River AOC musky rehabilitation project. • Restore priority wetlands • Support lake managers in restoring pelagic fish community – lake trout and ciscoes

4. Education and Awareness Strategies

Conservation outcomes frequently rely upon strategies that influence education and awareness of agencies and organizations as well as communities and individuals, all of whom directly and indirectly benefit from a healthy Lake Huron ecosystem. Here we propose a suite of strategies designed to incorporate biodiversity values into resource management decisions.

Strategy 4.1	Enhance knowledge, technical skills and information exchange to build capacity of local policy and land use planning authorities to include biodiversity values into their decisions.

Objectives:

1. Key land use decisions in priority watersheds include biodiversity considerations.

Strategic Action(s):

- Develop and implement a communications strategy including knowledge transfer to planners and decision makers.
- Host transfer of technology workshops in selected areas where Nearshore Zone conservation and protection is critical yet management capacity is limited.
- Update and/or make technical guides and shoreline management plans available to ensure that coastal and Nearshore Zone ecological values and physical processes are conserved.
- Technical guidelines concerning identification and management of hazardous lands is outdated and should be updated to include ecological protection; thereby aiding planning documents and official plans to include provisions for the identification and protection of the bio-physical processes, functions, and biodiversity conservation within the coastal and Nearshore Zone ecosystems.
- Develop outreach and education strategies to implement technology transfer.
- Develop and implement plans and protocols for basin-wide reporting on coastal/nearshore biodiversity status and trends on a five year cycle and customized for planners and decision makers. Seek innovative ways to reach other key audiences.

Related Strategies:

- Strategy 1.5 – Zone and protect priority/sensitive areas.
- Strategy 1.1 – Effectively conserve a system of public and private conservation lands for Coastal Terrestrial System and Nearshore Zone features that are resilient to changes in land use and climate.
- Strategy 2.6 – Develop and implement programs that delineate, evaluate and designate sensitive areas for protection.
- Strategy 1.3 – Conserve priority coastal habitats that are unprotected and vulnerable to loss and degradation.
- Strategy 1.6 – Increase protection of existing inland wetlands.
- Strategy 2.34 – Classify agricultural drains with regard to fishery habitat potential and work with drain commissioners to improve habitat.
- Strategy 2.4 – Develop comprehensive coastal management initiatives at U.S. and Canadian pilot sites.
- Strategy 2.26 – Improve road-stream crossings to reduce sedimentation.

Recommended Scale for Implementation:

- Regional/Local.

Opportunity Areas for Implementation:

- TBD - not identified during regional workshops.

Strategy 4.2	Better educate the public on climate change issues: by creating credibility and a sense of urgency for climate change mitigation strategies being implemented across the basin, and by providing information about observed and expected climate changes affects in Lake Huron that is easily understood.

Objectives:

1. Politicians in priority areas understand the value of ecosystem services of Lake Huron biodiversity and how the system of publicly and privately conserved lands and water will benefit their constituencies and help them adapt to climate change.
2. At least 25% of landowners in priority areas take ecologically responsible actions in shoreline management to adapt to climate change, including: floating docks, replanting of native vegetation, removal of shoreline hardening structures, etc.

Strategic Actions:

- Synthesize existing information about value of ecosystem services of Lake Huron biodiversity in an accessible and user-friendly format.
- Develop a climate change educational module for a suite of audiences (managers, decision makers, land owners).
- Develop clearinghouse of data and knowledge to communicate climate change information on biodiversity from multiple efforts (e.g., The Nature Conservancy, NOAA, USFWS, etc.)

Related Strategies:

- Strategy 4.3 – Increase community engagement, awareness, understanding and commitment to Coastal Terrestrial System and Nearshore Zone conservation.
- Strategy 6.1 – Develop economic incentives for ecosystem services programs.
- Strategy 8.2 – Assess the value of ecological goods and services provided by Lake Huron, including how values are altered under climate change scenarios.

Recommended Scale for Implementation:

- Lake Huron Basin-wide

Opportunity Areas for Implementation:

- TBD - not identified during regional workshops.

Strategy 4.3	Increase community engagement, awareness, understanding, and commitment to Coastal Terrestrial System and Nearshore Zone conservation.

Objectives:

1. Existing reporting methods include a biodiversity component to report on status and trends of biodiversity conservation features, key ecological attributes, and indicators in easily accessible formats.
2. Innovative communication strategies to increase public and stakeholder awareness of coastal and Nearshore Zone ecological processes, values, and conservation opportunities and being implemented.

Strategic Actions:

- Educate and engage land use planners and decision makers of Aboriginal and Tribal groups and municipalities, through workshops on coastal and Nearshore Zone ecological processes, values, and conservation opportunities.
- Educate the public on low impact development opportunities such as shoreline structures

that permit natural water flow and physical processes, and soft-shore engineering techniques. • Involve the public in shoreline planning activities, stewardship, and conservation efforts. • Integrate science and policy such that the general public can understand the importance of protecting coastal and Nearshore Zone biodiversity, processes, and functions, as well as the impacts of existing and planned development. • Communicate to the public the implications of land owner actions and the cumulative effects of shoreline alteration. • Involve all agencies, Aboriginal groups, user groups, and civil society in the decision-making processes and consensus building to ensure more consistent initiatives, and a feeling of collective responsibility that will lead to a more informed governance of activities and uses related to the coastal and Nearshore Zone ecosystems of Lake Huron. • Create a Lake Huron Biodiversity Atlas that provides science-based information in a public friendly format and which highlights the condition and treats to biodiversity conservation features and proposed conservation tools and strategies. • Target existing stewardship guidelines to private non-farm residents and cottagers.
Related Strategies: • Strategy 2.31 – Educate federal, state and local provincial governments on the need for targeted best management practice implementation support. • Strategy 4.1 – Enhance knowledge, technical skills and information exchange to build capacity of local policy and land use planning authorities. • Strategy 4.4 – Provide stakeholder education or outreach programming (end-use consumers and industries) to affect spread of invasive species. • Strategy 4.5 – Conservation groups proactively promote best management practices. • Strategy 4.6 – Improve quality and quantity of field services/tech support for implementation of best management practices.
Recommended Scale for Implementation: • Regional/Local
Opportunity Areas for Implementation: • TBD - not identified during regional workshops.

5. Law and Policy Strategies

A comprehensive biodiversity conservation strategy relies on the implementation of a range of activities from on-the-ground protection and restoration to education and outreach and equally important, law and policy strategies. Below we highlight one highly ranked strategy to address a pervasive threat across the entire Great Lakes basin.

Strategy 5.1	Eliminate ballast water as a vector for invasive species introductions.
Objective(s): 1. Elimination ship ballast water as a vector for organisms entering Great Lakes waters.	
Strategic Action(s): • Investigate policy options for promoting ballast water treatment technologies. • Build capacity for oceanic ships and Lakers to treat ballast water.	

• Raise awareness among community members of ballast water issues. • Develop and implement regulations. • Communicate the implications of ballast water as a vector for invasive species to the public (ex. fact sheets, workshops, information sessions). • Implement existing ballast and residual technologies (i.e. brine treatment) at major ports. • Investigate solutions to Laker issue. • Continue to monitor compliance and efficacy of the Seaway ballast water.
Related Strategies: • None identified.
Recommended Scale for Implementation: • Great Lakes Basin-wide.
Opportunity Areas for Implementation: Canada & United States • All major shipping ports within the Lake Huron basin, for example: Goderich, Owen Sound, Parry Sound and Sault Ste Marie

6. Livelihood, Economic and Other Incentives Strategies

The expansion of conservation strategies from site-based projects to law and policy is frequently more successful with the adoption of livelihood, economic, and other incentive strategies. Here we propose a strategy directed at recognizing and rewarding activities that provide payments for ecosystem services provided by conservation and management activities.

Strategy 6.1	Develop economic incentives for ecosystem services programs.
Objective(s): 1. Pilot markets (at least two) are developed and established that result in payments to farmers to implement BMPs to reduce NPS pollution (e.g., sediment, phosphorous, nitrogen) in priority watersheds.	
Strategic Action(s): • Identify markets for ecosystem services. • Conduct analyses—and monitoring where needed—to evaluate economic benefits of various BMPs. • Educate public (including farmers) of the potential social, economic, and environmental benefits of targeted BMPs. • Establish institutional and delivery mechanisms to develop ecosystem service markets.	
Related Strategies: • Strategy 2.1 – Implement an integrative approach to barrier management that accounts for ecological and social values. • Strategy 2.33 – Promote the development and implementation of alternative strategies to deal with waste (e.g., biodigestion). • Strategy 4.1 – Enhance knowledge, technical skills and information exchange to build capacity of local policy and land use planning authorities. • Strategy 5.3 – Strengthen or draft trade policy/regulation for invasive species.	

- Strategy 6.2 – Conduct evaluation of ecological, social, economic, and ecosystem service benefits of targeted best management practices, especially with emphasis on how benefits are influenced under climate change scenarios.
- Strategy 8.2 – Assess the value of ecological goods and services provided by Lake Huron, including how values are altered under climate change scenarios.

Recommended Scale for Implementation:

- Lake Huron Basin-wide

Opportunity Areas for Implementation:

Canada & United States

- Evaluation of watershed economic incentives through phosphorus trading for Lake Simcoe pilot study in Ontario: http://www.conservation-ontario.on.ca/projects/pdf/fact%20sheets/PHASE%20I/watershed_economic_incentives_english.pdf
- The Conservation Effects Assessment Project (CEAP) is working toward quantification of the services provided by agricultural BMPs.
- While the Alternative Land Use Services (ALUS) program and Payment for Ecological Good and Services (PEGS; http://www.cielap.org/pdf/HuronCounty_KateMonk.pdf) program were developed to promote public investment in compensating farmers for the ecological services they provide when they implement BMPs, there is potential for this program to utilize private markets.
- Since the public wants conservation practices on farms, there is potential to build markets for products grown on "BMP farms."
- For areas with planning for ecotourism or greenways (e.g., Saginaw Bay http://www.greeninfrastructure.net/sites/greeninfrastructure.net/files/4-FINALSag%20Bay%2007.18.05.pdf), there may be opportunities for municipal investment in funding to increase agricultural BMPs.

7. External Capacity Building Strategies

With the development of the Lake Huron Biodiversity Conservation Strategy two highly ranked strategies that address external capacity building emerged. These strategies address both information management as well as invasive species management.

Strategy 7.1	Develop and implement a data and knowledge management system designed to guide future conservation actions and effectively track implementation efforts.

Objective(s):

1. Recommendations of the GLRC Indicators and Information Strategy Team (GLRC 2005) are implemented.

Strategic Action(s):

- See: Great Lakes Regional Collaboration (GLRC) Strategy (December 2005) Indicators and Information Team, for the need to develop a comprehensive repository of Great Lakes data with a regional infrastructure and standardized data management protocols.

• Host transfer of technology workshops in selected areas where Nearshore Zone conservation and protection is critical yet management capacity is limited. • Update and/or make technical guides and shoreline management plans available to ensure that coastal and Nearshore Zone ecological values and physical processes are conserved. • Develop and implement a communications strategy including knowledge transfer to planners and decision makers.
Related Strategies: ▪ None identified.
Recommended Scale for Implementation: • Great Lakes Basin-wide.
Opportunity Areas for Implementation: • Throughout the Great Lakes Basin.

Strategy 7.2	Form a SWAT Team to eradicate new invasive species before establishment/naturalization.
Objectives: 1. Establish a Lake Huron Monitoring and Rapid Response Committee.	
Strategic Action(s): • Establish a Lake Huron Monitoring and Rapid Response Committee including terms of reference. • Form a multi-agency, rapid response committee with the authority to respond to new invasive species. • Develop rapid response plans for key species groups and priority potential invaders. • Identify legislative barriers/permits required for actions in each jurisdiction. • Determine "Authority" of SWAT team. • Develop agency protocols for "fast-tracking" necessary permits and legislative requirements. • Implement surveillance protocols around major shipping ports within Lake Huron and other identified hot spots (e.g. mouth of TSW).	
Related Strategies: • Strategy 2.12 – Prevent spread of invasive species predicted to spread due to climate change. • Strategy 2.18 – Promote and support Integrated Pest Management (IPM) for invasive species. • Strategy 2.19 – Increase application of effective controls of invasive species. • Strategy 2.20 – Implement Hazard Analysis Critical Control Points (HACCP): Increase application of effective risk management strategies for invasive species. • Strategy 2.21 – Monitor white-list species and promote native species over non-native species. • Strategy 2.22 – Improve barriers at canals. • Strategy 5.1 – Eliminate ballast water as a vector for invasive introductions. • Strategy 8.3 – Develop Lake Huron-wide risk assessment that informs strategies for the prevention of invasive species. • Strategy 8.4 – Conduct place-based research and development for the control of non-native invasive species.	

Recommended Scale for Implementation:
- Lake Huron Basin-wide.

Opportunity Areas for Implementation:
Canada & United States
- Concentrate surveillance around major ports and other identified hotspots to enable early detection of aquatic invaders.
- Concentrate terrestrial surveillance on disturbed urban areas
- Concentrate terrestrial surveillance on identified rare community types and protected areas

8. Research Strategies

While the conservation and resource management community of the Lake Huron basin has achieved tremendous success over the past decades, there still remain gaps in our basic scientific knowledge that limit our ability to implement a comprehensive biodiversity conservation strategy. Here we highlight a suite of strategies designed to fill such gaps.

Strategy 8.1	Establish a system for monitoring biodiversity and climate change in sentinel watershed sites.

Objective(s):
1. Impacts of climate change on biodiversity features are understood leading to the successful implementation of climate change adaptation strategies by federal, provincial/state and local governments and Lake Huron watershed residents.

Strategic Action(s):
- Catalogue efforts that monitor climate change impacts.
- Build consensus and efficiencies among monitoring efforts by establishing a monitoring network.
- Develop clearinghouse of data and knowledge to communicate information from multiple efforts.

Related Strategies:
- None identified.

Recommended Scale for Implementation:
- Great Lakes Basin-wide.

Opportunity Areas for Implementation:
Canada & United States
- Thunder Bay National Marine Sanctuary is a U.S. National Oceanographic and Atmospheric Administration Climate Change Sentinel Site.
- Great Lake Observing System may be able to be used in a network of climate change monitoring efforts.

Strategy 8.2	Assess the value of ecological goods and services provided by Lake Huron, including how values are altered under climate change scenarios
Objectives: 1. The values of ecological goods and services provided by the biodiversity features of Lake Huron are understood and guide the implementation of key conservation strategies.	
Strategic Action(s): • Conduct pilot studies to quantify the economic value of ecosystem services, including, but not limited to: the Nearshore Zone; coastal zone; riparian upland; Coastal Wetlands; beaches, tributary mouths, and riparian upland. • Ascertain and support existing initiatives that estimate the economic value of ecologically important and irreplaceable natural resource contained within Lake Huron. • Complete a trade-off analysis or benefit-cost analysis to evaluate the merits of proposed land use changes and development applications. • Support existing efforts such as the 'North Channel/Eastern Georgian Bay Economic/Fisheries Revitalization Initiative" in baseline information gathering, ecological assessment (classifying stream channels), strategic planning, economic assessment, goals, objectives and strategy development and implementation.	
Related Strategies: • Strategy 2.1 – Implement an integrative approach to barrier management that accounts for ecological and social values. • Strategy 2.33 – Promote the development and implementation of alternative strategies to deal with waste (e.g., biodigestion). • Strategy 4.1 – Enhance knowledge, technical skills and information exchange to build capacity of local policy and land use planning authorities. • Strategy 5.3 – Strengthen or draft trade policy/regulation for invasive species. • Strategy 6.1 – Develop economic incentives for ecosystem services programs. • Strategy 6.2 – Conduct evaluation of ecological, social, economic, and ecosystem service benefits of targeted best management practices, especially with emphasis on how benefits are influenced under climate change scenarios.	
Recommended Scale for Implementation: • Lake Huron Basin-wide.	
Opportunity Areas for Implementation: • TBD - not identified during regional workshops.	

Strategy 8.3	Develop a Lake Huron-wide risk assessment that informs strategies for the prevention of invasive species.
Objectives: 1. Develop an International Risk Assessment Framework	
Strategic Action(s): • Identify individual and organization to lead this initiative. • Establish risk assessment framework, binational investment/commitment. • Form a multi-agency task team to develop international risk assessment framework (identify the agency/leader) and promote associated education and awareness programs	

• Identification of risky species/pathways for Lake Huron. • Investigate policy and regulations for managing risk related to pathways. • Increasing awareness of high risk species/vectors. • Increasing effectiveness of education and outreach change.
Related Strategies: • None identified.
Recommended Scale for Implementation: • Lake Huron Basin-wide.
Opportunity Areas for Implementation: • TBD - not identified during regional workshops.

Strategy 8.4	Conduct place-based research and development of control techniques non-native invasive species.
Objective(s): 1. Complete place-based research and development for the control of non-native invasive species.	
Strategic Action(s): • Identify appropriate sites, with agency/public commitment, for experimental management research activities. • Research new control methods and tools • Testing and adaptively modifying existing control methods and tools • Identify Target: Location • Identify Target: Invasive Species • Identify Specific Sites Serving as MODELS or case studies for control experiments • Identify existing research opportunities and/or potential partners • Identify /Document field research and development opportunities • Identify agencies and public committed to research and development • Identify other possible partners (i.e. other researchers that may be interested) • Build on existing place-based research and development initiatives ex. Phragmites work by the Lake Huron Coastal Centre for Conservation and Ontario Federation of Anglers and Hunters (OFAH), DFO sea lamprey control research, University of Windsor goby management tools. • Identify research and development needs • Identify existing agency owned sites that may be appropriate • For new initiatives, work to secure funding. • Guide the development of place-based research and development at specific sites (see priority areas) throughout the Lake Huron basin. • Prioritize species and management tools to be tested. • Identify agencies and public groups that are willing to commit to working on place-based research. Secure funding for new initiatives. • Identify agencies and public groups that are willing to commit to working on place-based research. • Secure funding for new initiatives.	
Related Strategies: • None identified.	

Recommended Scale for Implementation: • Regional/Local.
Opportunity Areas for Implementation: Canada: Southeast Shores • Phragmites control at Bruce National Park in Singing Sands (former Dorcas Bay); Oliphant on Municipal Park near piping plover nests and in municipal dock facilities; Ipperwash. North Shore: • Eurasian Milfoil control at West and East of Blind River; North of La Cloche Island • Round Goby control at Manitoulin Island – Lake Wolsley (possibly) Southern Georgian Bay: • Phragmites control at Bruce Peninsula; Wasaga Beach PP; Collingwood shoreline (Silver Creek Wetland Complex) United States • TBD - not identified during regional workshops.

Strategy 8.5	Conduct a comprehensive assessment of key action areas for mitigation of agriculture, urban, and forest non-point source pollution, with special regard for areas important to biodiversity features and areas where climate change is anticipated to exacerbate current problems.
Objective(s): 1. Identify a nested suite of priority areas for the promotion of agricultural Best Management Practices (BMP) 2. Identify a nested suite of priority areas for forestry BMP promotion 3. Develop a nested suite of priority areas for urban/rural development BMP promotion 4. Create a system to track (who, what, when, where) and coordinate NPS	
Strategic Action(s): • Fund and initiate analyses to identify primary agricultural, urban, and forest NPS areas within a nested spatial hierarchy that includes the entire Lake Huron Basin • Fund and initiate a tracking system to coordinate and track various non-point source efforts • Develop a nested spatial hierarchy (lakewide, regional, watershed) for prioritizing NPS actions • Conduct analyses to identify primary agricultural, urban, and forest NPS areas • Conduct analyses to identify potential changes in priority areas under different future climate scenarios • Conduct analyses relating non-point runoff to biodiversity features, and prioritize accordingly • Develop a schedule for conservation actions addressing: who, what, and when • Create a tracking system to coordinate and track different non-point source efforts • Conduct strategic monitoring to determine the effectiveness of BMPs in addressing non-point runoff, especially in light of climate change	

Related Strategies:
• Strategy 2.2 – Implement improved septic technologies, including conversion of targeted septic systems to municipal or communal sewage systems. • Strategy 2.3 – Implement targeted agricultural best management practices (BMPs) to address non-point source pollution impacts to Lake Huron biodiversity. • Strategy 2.4 – Develop and implement an integrative, adaptive, and harmonized framework for coastal management within selected US and Canadian geographic regions. • Strategy 2.5 – Restore priority Coastal Terrestrial System and Nearshore Zone features. • Strategy 2.6 – Develop and implement programs that identify and conserve priority Nearshore Zone and Coastal Terrestrial System habitats.
Recommended Scale for Implementation: • Lake Huron Basin-wide.
Opportunity Areas for Implementation: Canada & United States • Methodologies could be established in priority areas identified in Strategy 2.4 and then applied basin-wide to improve future targeting of BMP implementation.

Strategy 8.6	Enhance research and monitoring of the Nearshore Zone and Coastal Terrestrial System margin.
Objective(s): 1. Researchers and management agencies are aware of the critical information gaps and operationalize inventory, monitoring and research programs to understand coastal and Nearshore Zone ecosystem status and trends (should include gaps in aquatic and terrestrial natural history, bio-physical processes, threats and regulatory and policy status and needs).	
Strategic Action(s): • Complete a science and research gap analysis to establish information needs that can be addressed via the Cooperative Science and Monitoring Initiative and/or other initiatives. • Establish baseline information for the coastal and Nearshore Zone ecosystems (e.g., index of shoreline alteration, wetland distribution and quality, fish communities, Nearshore Zone substrate and habitat). • Harmonize existing Nearshore Zone and coastal wetland indicators and further develop appropriate binational indicators including indicators of climate change. • Establish a quantitative relationship between the cumulative impacts of shoreline alteration and Nearshore Zone bio-physical processes. • Enhance and/or develop systematic, long-term, basin-wide nearshore/coastal monitoring programs to monitor and track the status and trends of biodiversity conservation features and key species and identify remaining high-quality coastal and Nearshore Zone habitat. • Improve the detail and accessibility of Nearshore Zone bathymetry and develop spatially explicit surficial geology to measure and classify Nearshore Zone aquatic habitats. • Complete a binational Coastal Wetland and Nearshore Zone reef inventory and assessment and ensure information is easily accessible.	

- Determine the impact of climate change on the hydrology of wetlands in GB and predict changes in connectivity of representative sentinel sites with declining water levels.
- Develop a Geographical Information System - Decision Support System (GIS/DSS) to compile, integrate and analyze multiple data sources on the coastal and Nearshore Zone ecosystem to identify the current status, temporal trends, and to project future impacts of land-use and climate change scenarios.
- By 2011, complete a science and research gap analysis so that agency managers and scientists can fill information gaps via the Cooperative Science and Monitoring Initiative.
- Develop, where possible, harmonized binational Lake Huron coastal and Nearshore Zone indicators and establish monitoring and reporting programs.

Related Strategies:

- Strategy 2.3 – Implement targeted agricultural best management practices (BMPs) to address non-point source pollution impacts to Lake Huron biodiversity.
- Strategy 2.4 – Develop and implement an integrative, adaptive, and harmonized framework for coastal management within selected US and Canadian geographic regions.
- Strategy 2.5 – Restore priority Coastal Terrestrial System and Nearshore Zone features.
- Strategy 2.6 – Develop and implement programs that identify and conserve priority Nearshore Zone and Coastal Terrestrial System habitats.

Recommended Scale for Implementation:

- Lake Huron Basin-wide.

Opportunity Areas for Implementation:

Canada & United States

- Methodologies could be established in priority areas identified in Strategy 2.4 and then applied for basin-wide implementation.
- Inventory Nearshore Zone ecosystem (e.g., North Channel and Manitoulin Island) to understand water chemistry, physical processes and attributes, and biological community status and value
- Obtain bathymetric data (e.g., for the Spanish River) to inform rehabilitation projects
- Identify walleye management needs (e.g., in the Spanish, and Vermillion Rivers)
- Map the density of spawning reefs (e.g., surrounding Manitoulin Island) and begin an ecological assessment of fish habitat.

7. PRIORITY BIODIVERSITY CONSERVATION AREAS

Effective biodiversity conservation requires the identification of priority areas to focus limited resources (Margules and Pressey 2000). Approaches such as the mapping of biodiversity concentrations or "hot-spots" have been used to identify areas with high levels of biodiversity and conservation needs to direct the allocation of conservation resources – allowing society to "protect the most species per dollar invested" (Myers et al. 2000).

This section identifies priority biodiversity conservation areas in the Lake Huron study area for based on key biodiversity features. Priority areas for Coastal Wetlands, Coastal Terrestrial System features, Islands and Aerial Migrants were identified in a geographic information system (GIS) to analyze and map feature distribution and viability. Threats and conservation capacity were also identified and mapped. All mapping and analyses were completed in ArcMap, the main application of the ArcGIS 9.3.1 suite of GIS software (ESRI 2009). Criteria for the priority area analysis were based on the key ecological attributes and threats identified in stakeholder workshops, a review of the literature and subsequent consultation with experts. We then synthesized this analysis to identify the top areas for conservation of these biodiversity features.

The same analysis was not applied to the Open Water Ecosystem, Nearshore Zone, and Native Migratory Fish features. In the case of the Open Water Ecosystem features, their viability is limited by threats that cannot be addressed through placed-based conservation action. Thus, the identification of priority areas is not relevant. For the Nearshore Zone and Native Migratory Fish features, priority areas are definitely relevant. However, the comprehensive data needed to develop metrics of biological significance were not available across the whole Lake Huron basin. Sampling in fisheries management tends to be highly targeted to specific species of management significance. In some cases, data are recorded for the whole assemblage of fish; however, the current composition of fish in the Nearshore Zone and the current distribution of Native Migratory Fish species are not well documented. At the end of this section, a set of initial maps that show important features for Nearshore Zone fish within eight distinct subzones of the Nearshore Zone are presented (Schaeffer and Reid, pers. comm.). Comprehensive classification and mapping of the Nearshore Zone and species distributions remain key data gaps, one recognized in other Great Lakes planning documents including the Great Lakes Regional Collaboration Strategy.

7.1 Methodology

7.1a Data Collection and Preparation

This section identifies key datasets that were compiled to analyze biodiversity features within the Lake Huron basin and the pre-processing steps required to ready the data for analysis. The development of workable spatial units is discussed along with the collection and preparation of land cover, wetland, shoreline and species and community data.

Units of Analysis

The drainage basin of Lake Huron within the Great Lakes system defined the spatial extent of the study area; additional data layers were compiled within the basin to define workable units for analysis. A hydrology layer representing the Great Lakes was combined with the basin layer to delineate land from water areas.

Due to the complexity of the shoreline and high number of Islands in close proximity to the shoreline, particularly along the northern shore of Lake Huron and Georgian Bay, it was important to use data at the largest scale possible to accurately represent the shoreline. For Ontario, the hydrology layer was based on NRVIS drainage mapping ranging in scale from 1:10,000 in southern portions of the province to 1:20,000 in the north (OMNR 2006a). For Michigan, the watershed boundaries (Watershed Boundary Dataset 2009) were the largest scale available representing the shoreline. Watershed classification systems from Ontario (quaternary watersheds, (OMNR 2009) and for Michigan (Watershed Boundary Dataset 2009) were then combined with the basin layer to delineate watershed units on the mainland and on larger Islands throughout the study area. Island complexes, created through the Great Lakes Islands project (Henson et al. 2010) were then added to identify and define workable units for smaller Islands in the study area. All watersheds and island complexes were assigned a unique identifier based on unit type (watershed or complex) and name. The total area of each land unit within this layer was calculated.

The basin was further divided into Coastal Terrestrial System, nearshore coastal and open water units. A 2-km buffer was generated around the shoreline of Islands and the mainland to divide island complexes and watersheds into Coastal Terrestrial System zones (areas within 2 km of Lake Huron) and inland portions (areas greater than 2 km from Lake Huron). In addition, 500-m and 5-km buffers were also generated for use in the analysis; the 5-km buffer was subsequently intersected with the 2-km buffer to create a layer representing the 2- to 5-km buffer zone. Next, the nearshore coastal area was delineated by extending the watershed boundary out from the shoreline into the lake to the 30-m depth line mapped by National Oceanic and Atmospheric Administration bathymetric data (NOAA 2003). Finally, open water areas greater than 30-m depths were divided into four units based on Rutherford and Geddes' (2007) fish habitat classification. Again, unique identifiers were added to each coastal unit type based on corresponding watershed, island complex or open water name and the total area of each coastal unit was calculated. This coastal unit layer formed the main unit of analysis for the study.

Land Cover Data

The Provincial Land Cover Data Base produced by the Ministry of Natural Resources (OMNR 1999) was used to map land cover within Ontario. The data, derived from digital, multispectral LANDSAT Thematic Mapper data, consisted of 28 land cover classes mapped at 25-m resolution. For Michigan, the National Land Cover Dataset produced by the U.S. Geological Survey (2001) was used. The data were based on LANDSAT 7 imagery mapped at 30-m resolution and included 21 land cover classes. Both raster land cover datasets were clipped to the study area boundary then converted to polygon features.

The land cover data were reclassified into natural, disturbed and other land cover classes (see Table 19). The SELECT BY ATTRIBUTE feature of ArcMap was then used to select all natural land cover polygons from each land cover layer; these features were exported into new layers representing only natural land cover within the study area. Polygons were dissolved together to reduce the number of features for processing and then combined into one natural cover layer.

Table 19: Simplified land cover classification for the Lake Huron basin.

Land Cover	Provincial Land Cover (Ontario)	National Land Cover (Michigan)
Natural	Freshwater Coastal Marsh/Inland Marsh Deciduous Swamp Conifer Swamp Open Fen	Emergent Herbaceous Wetlands Woody Wetlands Herbaceous Shrub/Scrub

Land Cover	Provincial Land Cover (Ontario)	National Land Cover (Michigan)
	Treed Fen Open Bog Treed Bog Dense Deciduous Forest Dense Coniferous Forest Mixed Forest Mainly Deciduous Mixed Forest Mainly Coniferous Coniferous Plantation Sparse Coniferous Forest Sparse Deciduous Forest Alvar Recent Cutovers Recent Burns Old Cuts and Burns Mine Tailings, Quarries, and Bedrock Outcrop Water	Mixed Forest Deciduous Forest Evergreen Forest Barren Land Open Water
Disturbed	Settlement and Developed Land Pasture and Abandoned Fields Cropland	Developed, Open Space Developed, Low Intensity Developed, Medium Intensity Developed, High Intensity Hay/Pasture Cultivated Crops
Other	Unclassified (Cloud & Shadow)	

Coastal Wetland Data

Wetland data were compiled by the Great Lakes Coastal Wetland Inventory (Great Lakes Coastal Wetland Consortium 2004). The Great Lakes Wetland Consortium (GLWC) data identified the spatial location of Coastal Wetlands along with their hydrogeomorphic type. This layer was supplemented with wetland data from the OMNR's Ontario Base Mapping (OBM) (OMNR 2006b) and McMaster Wetland Inventory collected along the Georgian Bay coast (Chow-Fraser 2010).

Coastal Terrestrial System Data

Coastal data were provided by Environment Canada and NOAA (Environment Canada 2008, GLERL 1997). The two data sources were merged together into one layer and simplified into eight broad classes of shoreline types for analysis (based on the analysis done for SOLEC 2009; EPA & Environment Canada 2009; Table 20).

Table 20: Coastal Terrestrial System Classification

Class	Ontario (Environment Canada)	Michigan (GLERL)
Artificial	Retaining Wall/Harbour Structure/Breakwaters Rip Rap	Artificial
Sand Beach	Mixed Beach (50% Sand, 10% Pebble, 35% Cobble) Mixed Beach (50% Sand, 25% Pebble, 25% Cobble) Mixed Beach (50% Sand, 50% Cobble) Mixed Beach (50% Sand, 50% Pebble) Mixed Beach (60% Sand, 20% Pebble, 20% Cobble) Mixed Beach (60% Sand, 40% Pebble) Mixed Beach (70% Sand, 15% Pebble, 15%Cobble) Mixed Beach (70% Sand, 30% Cobble)	Baymouth-barrier Beach Sandy Beach/Dunes

Class	Ontario (Environment Canada)	Michigan (GLERL)
	Mixed Beach (70% Sand, 30% Pebble) Mixed Beach (80% Sand, 10% Cobble, 10% Boulder) Mixed Beach (80% Sand, 10% Pebble, 10% Cobble) Mixed Beach (80% Sand, 20% Boulder) Mixed Beach (80% Sand, 20% Cobble) Mixed Beach (80% Sand, 20% Pebble) Mixed Beach (90% Sand, 10% Pebble) Sand Barrier With Lagoon Sand Beach: Depositional Sand Beach: Erosional or Transitory	
Cobble Beach	Boulder Beach Cobble Beach Mixed Beach Mixed Beach (40% Boulder, 30% Cobble, 30% Sand) Mixed Beach (40% Pebble, 40% Cobble, 20% Boulder) Mixed Beach (40% Sand, 60% Pebble) Mixed Beach (50% Boulder, 30% Cobble, 20% Sand) Mixed Beach (50% Boulder, 50% Cobble) Mixed Beach (50% Cobble, 50% Boulder) Mixed Beach (60% Boulder, 20% Cobble, 20% Sand) Mixed Beach (60% Boulder, 30% Cobble, 10% Sand) Mixed Beach (60% Boulder, 40% Cobble) Mixed Beach (70% Boulder, 30% Cobble) Mixed Beach (70% Cobble, 30% Boulder) Mixed Beach (70% Pebble, 20% Cobble, 10% Boulder) Mixed Beach (80% Boulder, 20% Cobble) Mixed Beach (80% Cobble, 20% Boulder) Mixed Beach (80% Cobble, 20% Sand) Mixed Beach (80% Pebbles, 20% Boulders) Mixed Beach (80% Pebble, 20% Cobble) Mixed Beach (90% Cobble, 10% Boulder) Pebble Beach Pebble/Cobble Beach	Coarse Beach
Bluff	Exposed Sediment Bluff	High Bluff >15m; moderately to highly erodible
Clay Shoreline		Sandy/Silty Bank Clay Bank
Cliff	Exposed Bedrock Bluff 1-5 m elevation Exposed Bedrock Bluff greater than 5 m elevation	Low Bluff <15 m; moderately erodible Low Beach Bluff < 15 m; moderately erodible High Beach Bluff > 15 m; high to moderately erodible
Bedrock Shore	Shelving Bedrock Exposed Bedrock Bluff less than 1 m elevation	Bedrock-Resistant
Organic	Broad Wetland Fringing Wetland Low Vegetated Bank (Grass or Trees)	Low Riverine/Coastal Plain Open Shoreline Wetland Semi-protected Wetland

The shoreline data were produced at a much courser scale and did not exactly align well with the coastal unit layer. Therefore, Coastal Terrestrial System and nearshore coastal units were dissolved together to create larger Nearshore Zones. Furthermore, thiessen polygons were generated around all island complexes and then integrated into the Nearshore Zone layer to capture shorelines associated with each unit. All Nearshore Zones were given a unique identifier representing its original Coastal Terrestrial System/Island complex unit for reference.

Species and Community Data

Species and community data were collected from a variety of sources. The Natural Heritage Information Centre (NHIC) element occurrence database of tracked species and communities was obtained for Ontario. The 2005 NHIC data were available as a point layer (NHIC 2005). An updated 2009 layer, with polygon features, was later provided by NHIC to augment the 2005 data (NHIC 2009). Species and community data collected by Nature Conservancy of Canada (NCC 2009) between 2006 and 2009 were also used to compliment the NHIC data for Ontario. For Michigan, species and community element occurrences were obtained from the Michigan Natural Features Inventory (MNFI 2009).

The SELECT BY LOCATION feature was used to select all element occurrences within the 2-km Coastal Terrestrial System. A complete list of all unique element occurrences was generated and target species and communities were identified for Coastal Wetlands and Coastal Terrestrial System areas.

7.1b Analysis

The purpose of the analysis is to identify priority areas that should be protected to create a network of conservation lands. These areas are rated based on three factors: ecological significance, condition, and conservation capacity. A set of indicators for each factor were scored (see tables below) and the points added together to calculate an overall index that was displayed on maps with an eight natural break categories ranging from low to high.

Ecological Significance Analysis

An analysis for ecological significance was completed to identify the relative importance of each biodiversity feature. Indicators to assess priority are based on the key ecological attributes from the viability analysis for each biodiversity feature (Workshop I, and supplemental information). The analysis was completed for four biodiversity features for which there was sufficient information:

- Coastal Wetlands
- Coastal Terrestrial System
- Aerial Migrants
- Islands.

Coastal Wetlands

Three indicators were identified to measure coastal wetland ecosystem significance: wetland area, richness of tracked indicator species and richness of wetland types (Table 21).

Table 21: Indicators of the ecosystem significance of Coastal Wetlands.

Indicator	Poor- (0)	Poor+ (1)	Fair- (2)	Fair+ (3)	Good- (4)	Good+ (5)	V. Good- (6)	V. Good+ (7)
Wetland area within coastal unit	0%	1-5%	5-10%	10-20%	20-30%	30-40%	40-60%	>60%
Richness of tracked indicator species	0	1	2	3	4	5	>5	-
Richness of wetland types (GLWC)	0	1	2	3	4	5	>5	-

For wetland area, the wetland layer was intersected with the coastal layer with UNION. The area of all wetland polygon features in the intersected layer was calculated. The total area of wetland was then summarized by coastal unit identifier, and then the percentage of wetland area per coastal unit was calculated and reclassified according to the scoring scheme outlined in Table 21.

To calculate richness of tracked wetland indicator species, tracked species were selected then spatially joined with the coastal unit layer on a one-to-many basis. A new field was added and assigned a unique identifier, a combination of the coastal unit identifier and the common name of the species. The attribute table was then summarized based on this unique identifier field to identify the number of different species occurring within each unit then summarized again on coastal unit identifier to identify the total number of unique or different species. The resulting table was then joined back to the original coastal unit layer and scored.

For richness of wetland types, the GLWC wetland layer was intersected with the coastal unit layer. A new field was added and assigned a unique identifier based on the coastal unit identifier and hydro-geomorphic type (barrier beach; lacustrine, open shoreline; riverine, delta; etc.). The attribute table was summarized based on this unique identifier to determine the number of different wetland types within each coastal unit; this table was summarized by coastal unit to calculate the number of unique species within each coastal unit.

The three individual indicator scores were added together to create an index of ecosystem significance for Coastal Wetlands. No weights were implied, as it was assumed that each factor contributed equally to ecosystem significance. The resulting score was mapped into eight natural breaks representing the relative importance of each coastal unit for wetlands (lower to higher) (Figure 26).

What this map shows:
Coastal wetland biological significance is well distributed throughout the Lake Huron basin. While areas that are more pristine (see Coastal Footprint) are highly ranked here, southern areas rich in species and wetland types are ranked high as well. Highest scoring areas include Saginaw Bay, Bruce Peninsula, areas along Western Lake Huron and southern Georgian Bay

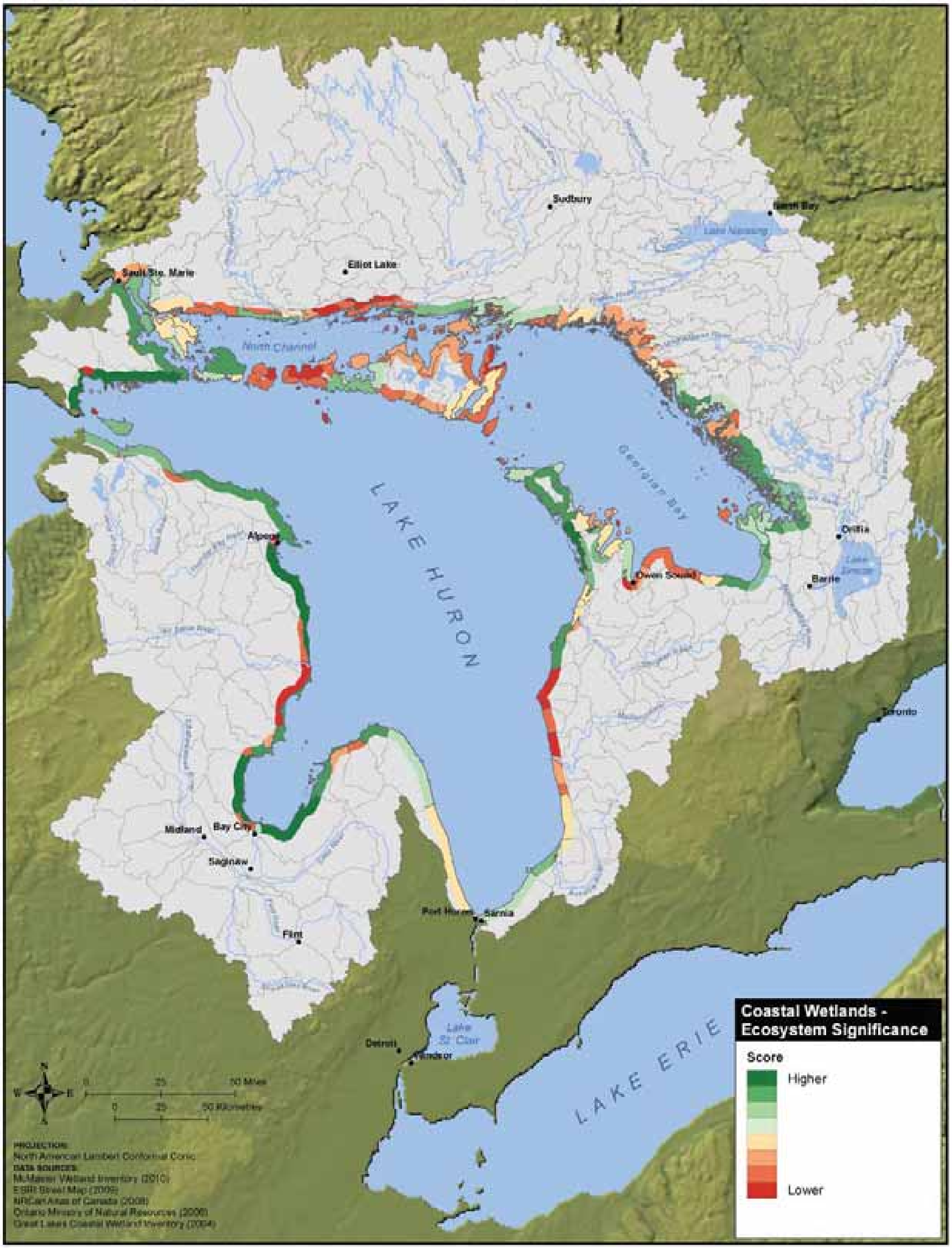

Figure 26: Coastal wetland ecological significance.

Coastal Terrestrial System

The Coastal Terrestrial System feature includes several different ecosystem types (e.g. sand beach, cobble beach), and as a result there are ten indicators to measure the ecosystem significance (Table 22).

Table 22: Indicators of ecosystem significance of Coastal Terrestrial System areas.

Indicator	Poor- (0)	Poor+ (1)	Fair- (2)	Fair+ (3)	Good- (4)	Good+ (5)	V. Good- (6)	V. Good+ (7)
Natural land cover within 2 km of shoreline (SOLEC 2008)	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Coastal complexity (length of coast: length of coastal unit)	1:1	1:2	1:3	1:4	1:5	1:6 – 1:7	1:8 – 1:9	1:10+
Sand beach within coastal unit (SOLEC 2008)	0%	1-5%	5-10%	10-20%	20-50%	50-70%	70-90%	>90%
Cobble beach within coastal unit (SOLEC 2008)	0%	1-5%	5-10%	10-20%	20-50%	50-70%	70-90%	>90%
Bluff within coastal unit (SOLEC 2008)	0%	1-5%	5-10%	10-20%	20-50%	50-70%	70-90%	>90%
Cliff within coastal unit (SOLEC 2008)	0%	1-5%	5-10%	10-20%	20-50%	50-70%	70-90%	>90%
Richness of tracked indicator species	0	1	2	3	4	5	>5	-
Richness of globally rare species	0	1	2	3	4	5	>5	-
Richness of globally rare vegetation communities	0	1	2	3	4	5	>5	-
Richness of Coastal Terrestrial System types (SOLEC 2008)	0	1	2	3	4	5	>5	-

Natural land cover within 2 km of the shoreline was computed for the coastal development footprint and applied here.

Coastal complexity was the second measure of ecosystem significance. The shoreline layer was intersected with the Nearshore Zone layer. The length of shoreline within each unit was calculated. The shoreline layer was then simplified using BEND SIMPLIFY. This tool removes small fluctuations and extraneous bends from the line while still preserving its essential shape (ESRI 2009). The simplified shoreline was intersected with the Nearshore Zones layer. The length of simplified shoreline was calculated and summarized per unit. The summary tables for each measure were joined to the attribute table of the units layer; coastal complexity was calculated by dividing the length of shoreline by the length of the coastal unit (simplified shoreline) and then assigned an indicator score.

To determine the percent of sand beach, cobble beach, bluff and cliff, the reclassified SOLEC data was intersected with the Nearshore Zone layer with UNION. Similar to artificial shoreline computed for coastal development footprint, new fields were added to the attribute table to represent the length of the different shoreline types and the total length of shoreline per unit. Features were selected based on shoreline type and length calculated in the appropriate attribute table. The length fields were then summarized by Nearshore

Zone units and the resulting table was joined back to the original units table to calculate the percentage of each shoreline type in each unit. The layer was then reclassified according to the scoring scheme.

Richness of tracked Coastal Terrestrial System indicator species was also computed. The tracked indicator species identified earlier were pulled from the element occurrence layer and spatially joined with the Coastal Terrestrial System units. A unique identifier field was created by combining the unit identifier with the species name. The attribute table was summarized based on the unique unit-species name to provide a count of the number of tracked species occurring within each unit. This table was again summarized, this time based on the unit identifier to count the number of unique species occurring within each unit. Scores were assigned based on richness.

The richness of tracked Coastal Terrestrial System indicator species and globally rare species and communities were additional indicators analyzed. All globally rare species and communities were selected; these elements had global ranking (GRANK) from extremely rare (G1) and very rare (G2) to rare and uncommon (G3). The selected species and community layer were intersected with the Coastal Terrestrial System units. A unique identifier field was created by combining the unit identifier with the species or community name. The attribute tables were summarized based on the unique unit-species and unit-community names to provide a count of the number of globally rare species and communities within each unit. The output tables were summarized again, based on the unit identifier to count the number of unique species and communities occurring within each unit. Each indicator was then scored based on the viability scoring assessment.

The final indicator was richness of Coastal Terrestrial System types. The broader SOLEC classes listed in Table 20 were used to assess type. The simplified SOLEC data were intersected with the Nearshore Zone layer. A new field was added, which was a combination of the Coastal Terrestrial System unit and terrestrial type. The attribute table was summarized on this new attribute to count the total number of occurrences within each unit. This table was then summarized based on Coastal Terrestrial System unit to provide a count of the total number of unique occurrences of coastal types.

The ten individual indicator scores were added together to create an index of ecosystem significance for Coastal Terrestrial System units. No weights were applied, as it was assumed that each factor contributed equally to ecosystem significance. The resulting score was mapped into eight natural breaks representing the relative importance of each coastal unit for Coastal Terrestrial System features (lower to higher) (Figure 27).

What this map shows: The highest scoring areas for Coastal Terrestrial System biological significance are found mostly in the northern two-thirds of the Lake Huron basin, with areas that are heavily used for agriculture scoring the lowest. The drivers include both concentrations of globally rare species and communities as well as diversity of shoreline; thus, the highest scoring areas are in Georgian Bay, the Bruce Peninsula, Manitoulin Island and the Presque Isle shoreline in the U.S.

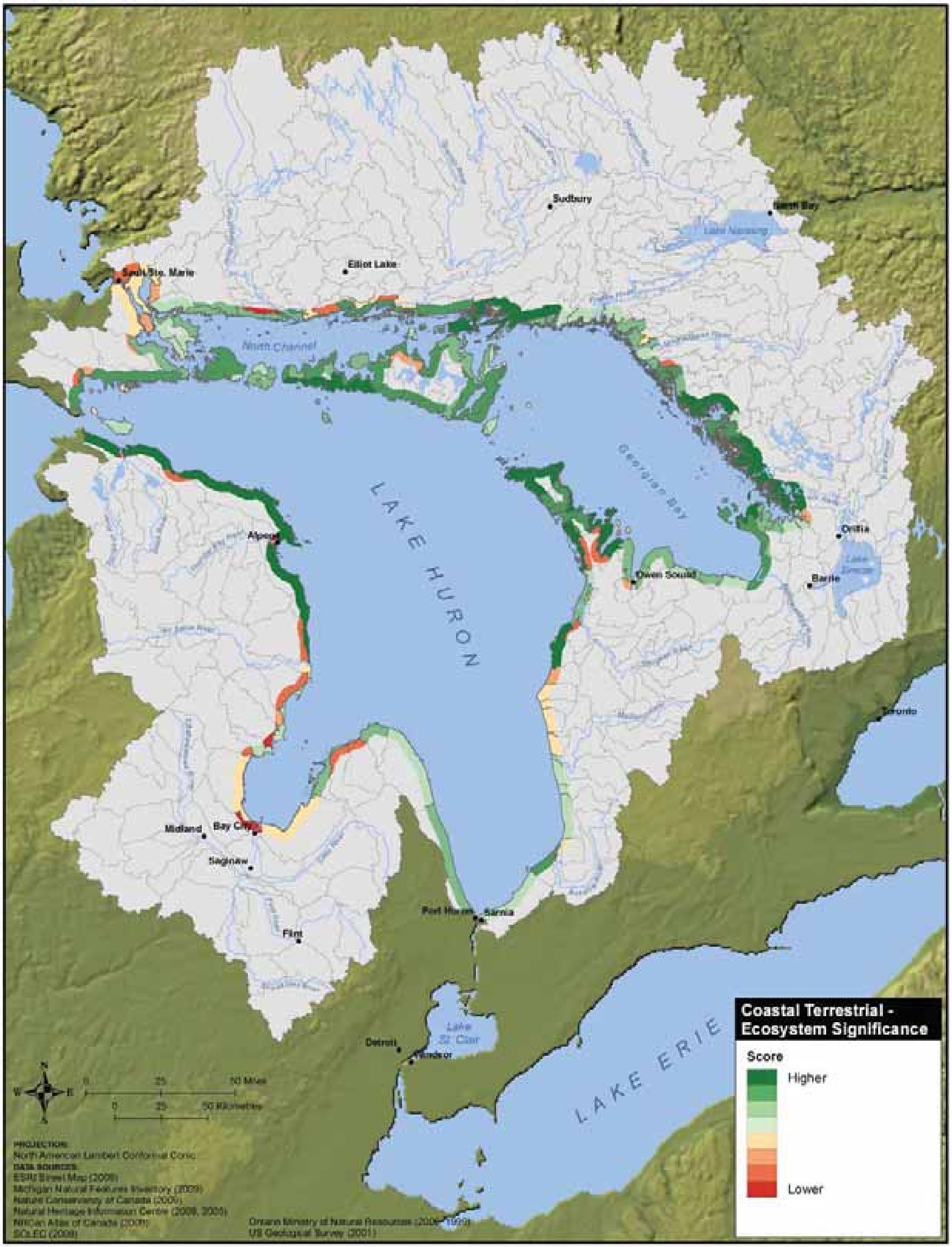

Figure 27: Areas of Coastal Terrestrial System biological significance for Lake Huron.

Aerial Migrants

The methodology developed by Ewert et al. (2006) to model migratory land bird stopover sites in the western Lake Erie basin was modified and applied to Lake Huron. Modeling for other aerial migrant groups was not done. The main determinants for identifying suitable land bird habitat were natural, or undeveloped, cover and the proximity of the undeveloped cover to hydrologic features and other cover. The natural land cover layer created earlier was used as input for the model. The Great Lakes shoreline layer and stream and waterbody layers for both Ontario (OMNR 2006a, 1:100,000) and Michigan (USGS 2009a, 1:100,000) were also used. The SELECT BY LOCATION feature was used to select all undeveloped land cover features within specified distances of the various attributes and assign a suitability score. Habitat was scored as having very low (1), low (2), medium (3), high (4) or very high (5) suitability based on stopover site preference attributes (Table 23). For example, all undeveloped land cover greater than 1.6 km from the Lake Huron shoreline were selected. Next, from this selection all cover less than 0.4 km from lakes or rivers were reselected. Then, from the remaining features, cover more than 0.2 km from shore was selected. Finally, a suitability score of 2, or low, was calculated for these features.

Table 23: Migratory land bird stopover site attributes (modified from Ewert *et al.* 2006).

Attribute	Suitability Score	
Undeveloped cover[1] < 0.4 km from Great Lakes shoreline	5	Very High
Undeveloped cover[1] > 0.4 km but < 1.6 km from Great Lakes shoreline	4	High
Undeveloped cover[1] > 1.6 km from Great Lakes shoreline and < 0.2 km rivers or lakeshores	3	Medium
Undeveloped cover[1] > 1.6 km from Great Lakes shoreline and > 0.2 but < 0.4 km from rivers or lakeshores	2	Low
Undeveloped cover[1] > 1.6 km from Great Lakes shoreline and > 0.4 km from rivers or lakeshores	1	Very Low

[1] Undeveloped cover includes all natural land cover classes excluding water/open water

The layer was dissolved based on suitability scores to limit the amount of features for processing. The results of the land bird model were then used to assess the ecosystem significance of migratory land birds.

One indicator of ecosystem significance for migratory land birds were computed (Table 24). Bird habitat scoring very high or high significance were selected and intersected with the study area units layers with UNION. New fields were added to the attribute table to calculate the total area of significant bird habitat in the Coastal Terrestrial System unit; total bird habitat area was summarized by coastal unit and the percentage of significant bird habitat was computed. Percentage values were then assigned a score from poor to very good based on the viability assessment.

As this model was originally created to map migratory stopover habitat in fragmented areas, and is not applicable to regions with high amounts of natural cover. This analysis was not applied to the Canadian Shield portion of the Lake Huron coast (that all have >40% land cover). These regions are still important for migrating birds, but stopover site availability is not a limiting factor.

Table 24: Indicators of ecosystem significance for migratory land birds.

Indicator	Poor- (0)	Poor+ (1)	Fair- (2)	Fair+ (3)	Good- (4)	Good+ (5)	V. Good- (6)	V. Good+ (7)
Very high or high significance stop-over habitat in coastal unit	<10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-80%	>80%

What this map shows: This map (Figure 28) shows where there is high quality stopover habitat that is still in need of protection and where there are gaps in stopover habitat along the coast. Restoration of stopover habitat in these areas would benefit migrating land birds. Areas where suitable cover is greater than 40% intact are not shown.

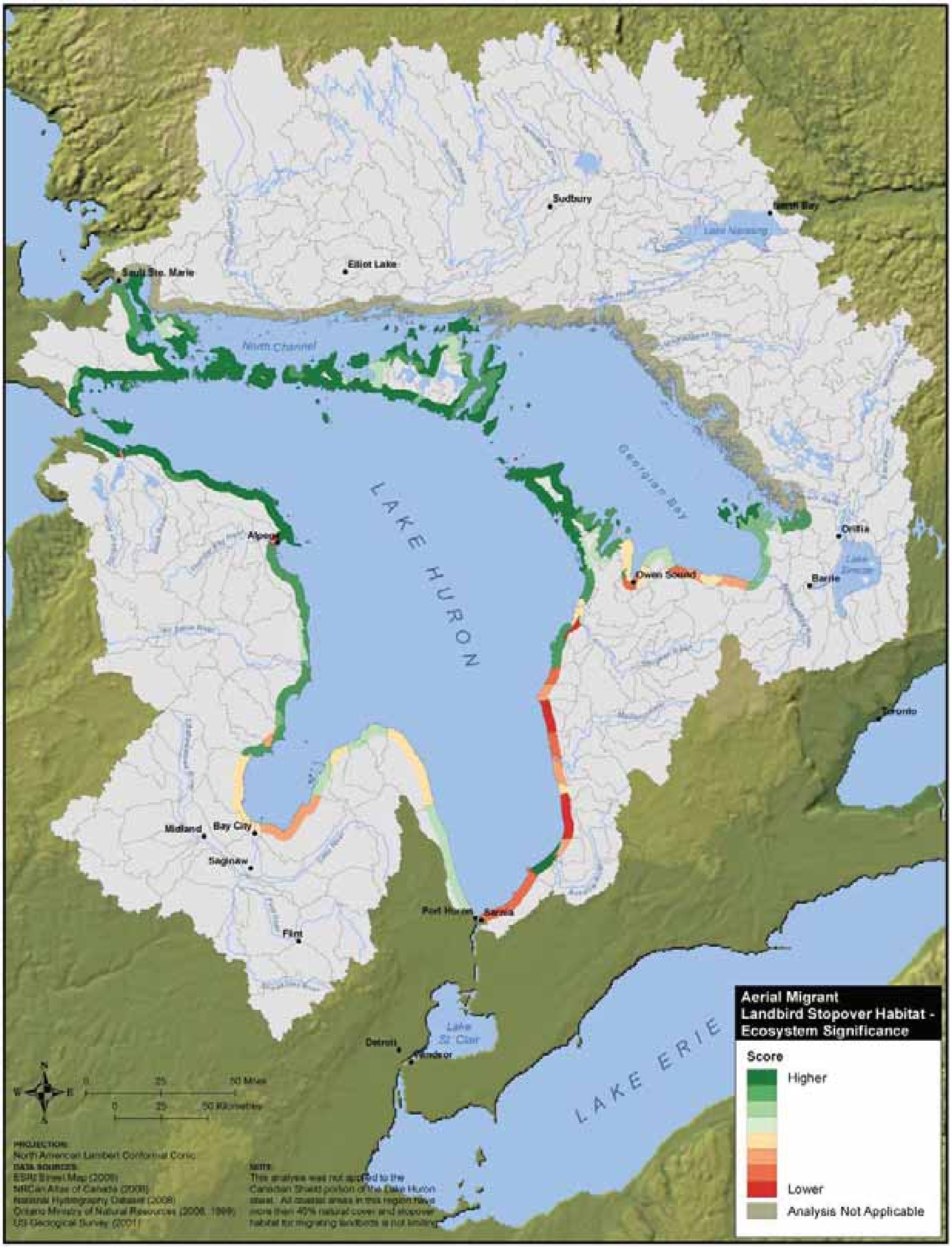

Figure 28: High quality stopover habitat that is still in need of protection and where there are gaps in stopover habitat along the coast.

Islands

The identification of priority Islands was based on the existing binational analysis (Henson et al. 2010). A GIS approach was used to score and analyze Islands within the Great Lakes. Polygons for Islands as well as reefs and submerged rocks that are periodically exposed were identified from a variety of the best available provincial and state digital layers.

In order to create manageable units for the analysis, Islands were grouped according to their Great Lakes coastal environment. Lake Huron has 11 of these units. The term coastal environment was coined from Owens (1979) and was used to further subdivide the Great Lake basin regions into 33 coastal environments in Ontario. These coastal environments are based on shore-zone sediment transport systems which are generally influenced by relief and geology, coastal zone characteristics (shore-zone character and beach character), fetch, wave exposure and ice, sediment availability and transport (Owens, 1979). This report splits some larger Islands (e.g. Manitoulin) into different zones to reflect distinctive coastal characteristics. In the United States, Islands were grouped according to their coastal reach based on the integrated SOLEC ecoreaches (SOLEC 2008). Seventy coastal reaches were identified through this process to address Nearshore Zones (terrestrial, Coastal Wetlands, aquatic). Each coastal reach was then renamed to integrate with the coastal environment naming conventions. Any coastal reach that overlapped with a Canadian coastal environment was renamed to the associated coastal environment.

Fluctuation of water levels subject low-lying Islands to periodic inundation. Depending on the water level, rocks and shoals may or may not be present within the best available digital mapping in order to distinguish and designate them as Islands. Therefore, some small Islands may not have been included or may not be treated separately from other Islands in the binational Islands dataset and were not included in the analysis.

Identifying Large Islands and Island Complexes

Portions of the Great Lakes (e.g. eastern Georgian Bay) contain thousands of Islands, many of which are very small, close together and have similar characteristics. These complexes of small Islands function as a landscape unit. Within each coastal environment large Islands and island complexes were identified. Large Islands were extracted based on the range of sizes of Islands within the coastal environment and maintained as a single unit of analysis. Clusters of small Islands were grouped into island complexes based on proximity (common coastal environment, within 200 m of each other and without any intervening land) and similar geology. The analysis was then done on the island complex, rather than small individual Islands.

Biodiversity Analysis

Islands and island complexes were scored based on a suite of scoring criteria to determine their associated conservation value by assigning each island or islands complex a total biodiversity score. Many biodiversity scoring criteria were based on the previous work of Ewert et al. (2004). The scoring criteria are summarized in Table 25.

Table 25: Biodiversity scoring criteria.

Measures for Scoring Criteria (all classes)		Scoring Category	Nation Analyzed
Biological Diversity			
Species			
C1	Diversity of Rare Species	all extant rare species Element Occurrences (EOs)	ON, US
C2	Colonial Nesting Waterbirds		ON, US
C2P1	Diversity of colonial waterbird use	Known breeding by selected species	ON, US
C2P2	Importance for colonial waterbird populations	Top breeding island sites for all species	ON, US
C3	Global Biodiversity Values - species		ON, US
C3P1		diversity of G1-G3 species	ON, US
C3P2		diversity of Great Lakes endemic species	ON, US
C3P3		diversity of Great Lakes disjunct species	ON only
C3P4		diversity of Great Lakes declining species	ON only
C4	Species At Risk (SAR)	Federal and/or provincial SAR (Endangered, Threatened, Special Concern)	ON only
Plant Communities			
C5	Diversity of Rare Plant Communities	all extant EOs of plant communities	ON, US
C6	Diversity of Globally Rare Communities	all extant G1-G3 occurrences	ON, US
Ecological Systems			
C7	Ecological system diversity (terrestrial)	Number of different natural ecological systems	ON, US
C8	Presence of key ecological systems		ON, US
C9	Presence of key shoreline combination type		ON, US
C10	Presence of rivers and streams		ON, US
C11	Presence of wetlands		ON, US
C12	Presence of lakes		ON, US
Ecosystem Functions			
C13	Isolation	distance from mainland and other classes	ON, US
C14	Birds		ON, US
C14P1		Presence of roosting, foraging shorebirds	ON only
C14P2		Presence of roosting, foraging waterfowl	ON only
C14P3		Stopover sites for land birds	ON, US
C15	Fish Habitat		ON, US
C15P1		Known occurrences of interjurisdictional fish species	ON, US
C15P2		Suitable habitat for interjurisdictional fish species	ON, US
Physical Diversity			
C16	Shape Complexity	area: perimeter ratio	ON, US
C17	Geological Diversity		ON, US
C17P1		Presence of key geology types	
C17P2		Number of different geology types	
C18	Shoreline Diversity	Number of different shoreline types	ON, US
Size			
C19	Size (Island or Island Complex)	based on 10 natural breaks within a coastal environment	ON, US
Distinctiveness			
C20	Similarity Index		ON only

What this map shows: This map (Figure 29) shows priority island complexes in Lake Huron that are identified in Henson et al. (2010).

Figure 29: Priority island complexes identified by Henson et al. (2010).

Condition Analysis

The second part of the analysis to identify priorities for conservation was an assessment of condition and potential threats. This is intended to identify those regions of the Lake Huron coast that are more vulnerable to immediate changes due to land use activities. The results of ecosystem significance and condition can be combined to better understand both areas with high significance that are under threat or are likely to have restoration needs, and areas with high significance that have relatively fewer factors that could threaten the biodiversity features.

Coastal Development Footprint

Six measures of condition were calculated and then assembled into a single index to assess the relative coastal development footprint for each coastal unit (Table 26). The footprint measure can be used to assess the condition of Coastal Wetlands, Coastal Terrestrial System, Islands and Aerial Migrants, and is a good approximation of Nearshore Zone condition as well. However, these metrics do not account for the impact of currents on determining Nearshore Zone water quality and sediment regimes. For Native Migratory Fish, there is a lack of comprehensive spatial layers of dams and other barriers essential to assessing condition for these features. The data that do exist are presented in the Threats section under dams and other barriers. For the Open Water Ecosystem, there is also a lack of spatial framework and data to map the condition "surface." This is currently a project of (David Allan, Peter McIntyre, and Ben Halpern).

Table 26: Indicators measuring coastal development for Coastal Wetlands, Coastal Terrestrial System and Nearshore Zones.

Indicator	Poor- (7)	Poor+ (6)	Fair- (5)	Fair+ (4)	Good- (3)	Good+ (2)	V. Good- (1)	V. Good+ (0)
Artificial shoreline within 2 km of shoreline	>60%	40-60%	35-40%	30-35%	25-30%	20-25%	10-20%	<10%
Natural land cover within 2 km of shoreline	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Natural land cover from 2 to 5 km from shoreline	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Natural land cover within watershed	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Road density within 2 km of shoreline (m road/ km^2)	>3000	2000-3000	2000-1500	1250-1500	1000-1250	500-1000	500-250	<250
Building density within 500 m of shoreline (number of buildings/km^2)	>400	200-400	150-200	100-150	75-100	50-75	10-50	<10

To determine the percent of artificial shoreline, the SOLEC data were intersected with the Nearshore Zone layer. Two new fields were added to the attribute table to represent the length of artificial shoreline and the total length of shoreline. All artificial shoreline features were selected and the length calculated. Next all shoreline features were selected and length calculated. The length fields were then summarized by Nearshore Zone. The percentage of artificial shoreline was calculated. The results were joined to the attribute table of the units layer and indicator scores assigned.

Next, the indicators for natural land cover were computed. The natural cover layer was intersected with the Lake Huron land units and 500-m, 2-km and 5-km buffers with the union tool, which computed the geometric intersection of all input features. New fields were added to the attribute table of the intersected layer to calculate the total amount of natural land cover within each buffer zone and the total area of land for each land unit and Coastal Terrestrial System zone. A series of select by attributes were then completed to calculate the geometry of each polygon that matched certain criteria. For example, all polygon features within 500 m of the shoreline were selected and areas calculated to determine the amount of land within 500 m of the shore. Select from current selection was then used to reselect only those features that were in natural cover, the areas of these features were then calculated to determine the amount of land 500 m from shore in natural cover. The intersected layer was dissolved based on the unique land unit identifier, and the total amount of land and natural cover within 500-m, 2-km and 2-5 km of the shoreline and within each watershed was summarized. Finally, the percentage of natural cover within each zone was calculated for each land unit.

Road density was calculated next. The Ontario (OMNR 2006b) and Michigan Road Network (Michigan Department of Natural Resources 2008) layers were merged together into one roads layer. The roads layer was then intersected with the Coastal Terrestrial System units. A new field was added to the attribute table to calculate the length in meters of all road segments within each unit. The length field was then summarized into a database file based on Coastal Terrestrial System unit and output as a database file. This file was then joined back to the units layer. A new attribute called road density was added and then calculated by dividing the total length of roads in each unit by the area of that same unit.

Housing density was calculated separately for Ontario (OMNR 2006b) and Michigan (U.S. Census Bureau 2000). For Ontario, housing data were available as point data and extracted from the Ontario building layer, which also contained the centroid of building footprints. All houses within 500 meters of the shore where selected and then spatially joined with the units layer. The resulting layer reported the total count of houses within each unit. Building density was then calculated by dividing the number of buildings by the area of the 500-m buffer within each unit. The 500-buffer area within each unit was calculated by intersecting the buffer with the units layer the calculating the geometry of all features, and summarizing by unit id.

For Michigan, census block data were used to provide an estimate of housing density within each watershed. Housing unit density per square kilometer was calculated for each census block. The census block data were then combined with the Lake Huron units (nearshore terrestrial) and 500-m buffer. The area of each polygon within this unioned coverage was calculated and then multiplied by the housing unit density to estimate the number of houses assuming housing units were evenly distributed across each census block. The polygons were then dissolved based on nearshore terrestrial unit and the total housing density was calculated by dividing the number of houses by total area of each unit in km^2.

The individual scores of the six indicators of the coastal development were added together to provide a total indicator of coastal footprint. No weights were applied, as it was assumed all indicators contributed equally. The resulting score was mapped into eight natural breaks representing the relative level of the coastal development footprint (lower to higher) within each coastal unit (Figure 30).

What this map shows: The greatest human impacts have occurred in the southern half of the Lake Huron basin, as would be expected given the location of industry, agriculture and urban areas.

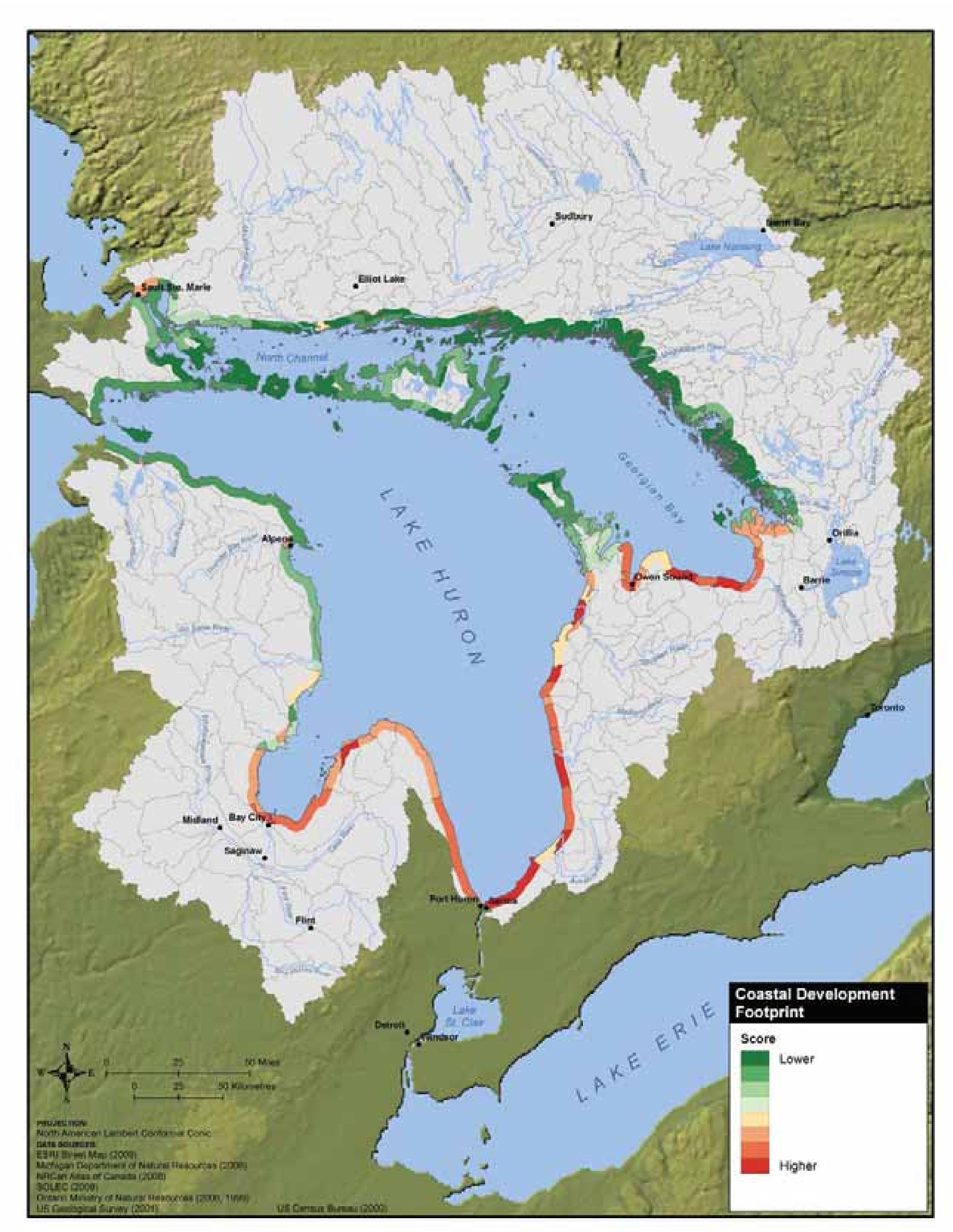

Figure 30: Coastal development or human impact around Lake Huron.

Conservation Capacity

The third and final measure to assess priority areas was conservation capacity. Conservation capacity includes ten different indicators, and is intended to provide an assessment of those coastal units where there is a higher probability of existing of conservation efforts. This can include both protected areas and institutions that have the mandate to support biodiversity conservation and management (Table 27).

Table 27: Conservation capacity indicators for Coastal Terrestrial System areas.

Indicator	Poor- (0)	Poor+ (1)	Fair- (2)	Fair+ (3)	Good- (4)	Good+ (5)	V. Good- (6)	V. Good+ (7)
Regulated protected area in coastal unit (see Table 28)	0%	1-5%	5-20%	20-30%	30-40%	40-50%	50-75%	>75%
Regulated protected area within 500 m of shore in coastal unit	0%	1-5%	5-20%	20-30%	30-40%	40-50%	50-75%	>75%
Protected areas and conservation lands in coastal unit (see Table 28)	0%	1-5%	5-20%	20-30%	30-40%	40-50%	50-75%	>75%
Protected areas and conservation lands within 500 m of shore in coastal unit	0%	1-5%	5-20%	20-30%	30-40%	40-50%	50-75%	>75%
Local Land Trust/Conservation Authority	No	-	Partial	-	Yes	-	-	-
Watershed Plan/319 Plans	No	-	Partial	-	Yes	-	-	-
Other Conservation Plan	No	-	Partial	-	Yes	-	-	-
Area of Concern	No	-	Partial	-	Yes	-	-	-
Biosphere Reserve	No	-	Partial	-	Yes	-	-	-
MI Environmental Areas	No	-	Partial	-	Yes	-	-	-

Data for protected areas were compiled from a variety of different sources. For Michigan, all conservation lands were provided from the Conservation and Recreation Lands Dataset (Ducks Unlimited and The Nature Conservancy 2008). For Ontario, various data layers were combined together (BTC 2009, EBC 2009, GBLT 2009, NCC 2009, OMNR 2006b, OMNR 2003, CWS 2002. The data were categorized into federally regulated, conservation lands and other (Table 28).

Table 28: Classification of protected areas.

Protected Area	Ontario	Michigan
Federally Regulated	National Parks Provincial Parks Conservation Reserves National Wildlife Areas Migratory Bird Sanctuaries	Federal Wildlife Reserves/Area Coastal State Game Areas Wildlife Areas State Wildlife Research Areas National and State Parks and Forests Conservation Areas (State-owned) Ecological Reserves (Federal) National Wildlife Refuges Michigan Natural Areas Wilderness Areas Wilderness Study Areas Wildlife Area

Protected Area	Ontario	Michigan
Conservation Lands	Conservation Authority Land Nature Conservancy of Canada Land Other Land Trusts County Forests	Nature Preserves (Private) Conservation Easements Plant Preserves (NGO)
Others	Areas of Natural & Scientific Interest Provincially Significant Wetlands	Conservation Reserve Enhancement Program Management of Existing Experimental Forests Forest Reserves (State of Michigan)

The federally regulated, conservation and other lands data layers along with the 500 m buffer were intersected with the units layer with UNION to create a combined data layer. New fields were added to the attribute table of the intersected layer to calculate the total amount of federally regulated and conservation lands within each Coastal Terrestrial System unit and 500-m buffer zone. A series of select by attributes were then completed to calculate the geometry of each polygon feature that matched certain criteria. For example, all polygon features within 500 m of the shoreline were selected and areas calculated to determine the amount of land within 500 m of the shore. Select from current selection was then used to reselect only those features that were federally regulated; the areas of these features were then calculated to determine the amount of land 500 m from shore that was federally regulated. The intersected layer was dissolved based on the unique land unit identifier, and the total amount of land and protected land within 500-m, 2-km was summarized. Finally, the percentage of protected land within each zone was calculated for each unit. The relative percentages were mapped into eight natural breaks (Figure 31).

Information on conservation organizations, plans and designations were extracted from several sources (DEQ 2009, NEC 2008, EC 2008, OMNR 2006). Percentage of each was computed and assigned a score where no=0%, partial=50% and yes=100%. The scores from the ten individual indicators of conservation capacity were combined together to create a measure of conservation capacity. No weights were applied, as it was assumed all indicators contributed equally. The resulting score was mapped into eight natural breaks (Figure 32).

What these map shows: Conservation capacity is geographically distributed across the Lake Huron basin. To the north, there are large areas of public lands and to the south there are both local institutions such as the Conservation Authorities in Ontario as well as watershed planning completed in Michigan that increase the capacity to do conservation.

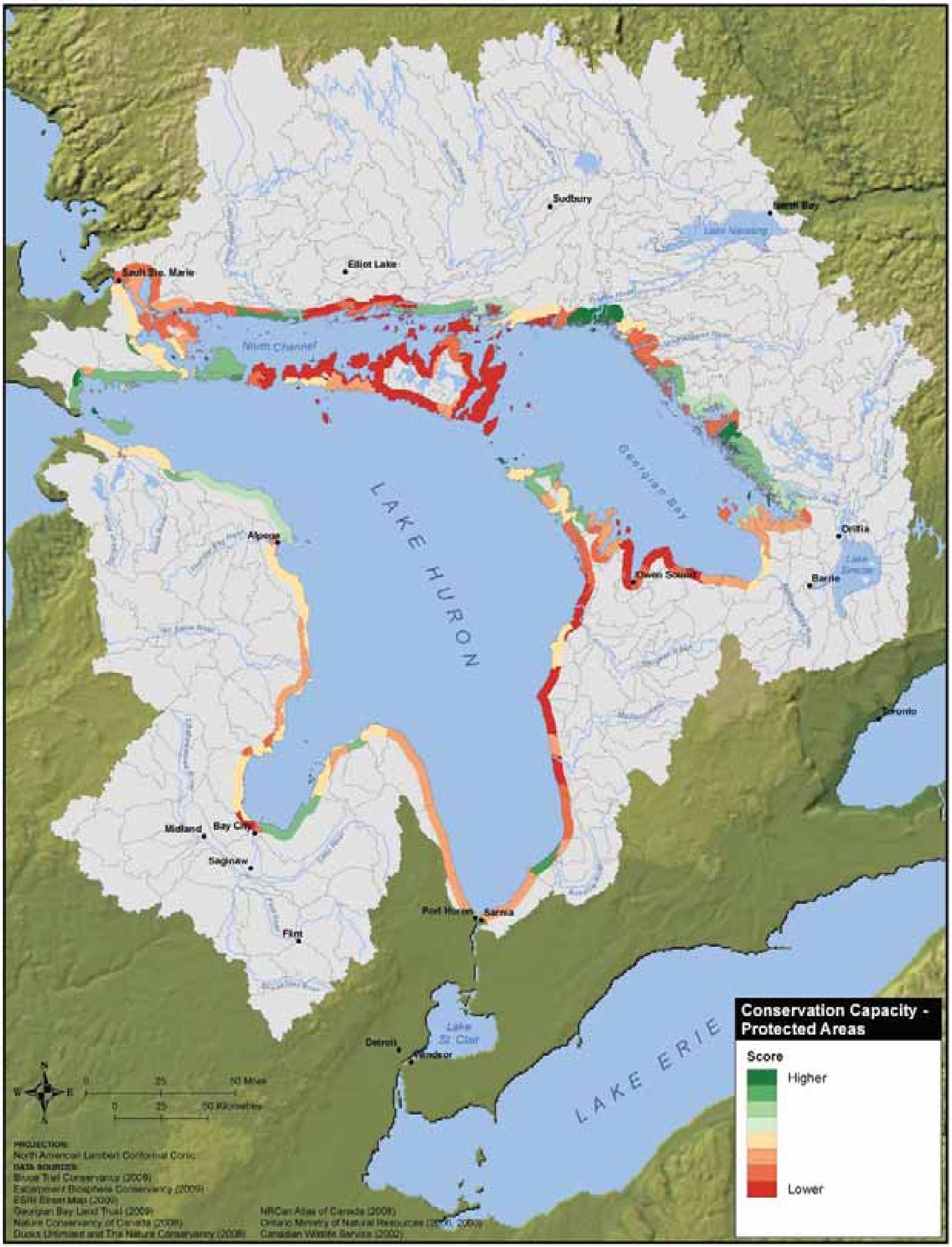

Figure 31: Conservation capacity – as measured by protected area - across Lake Huron.

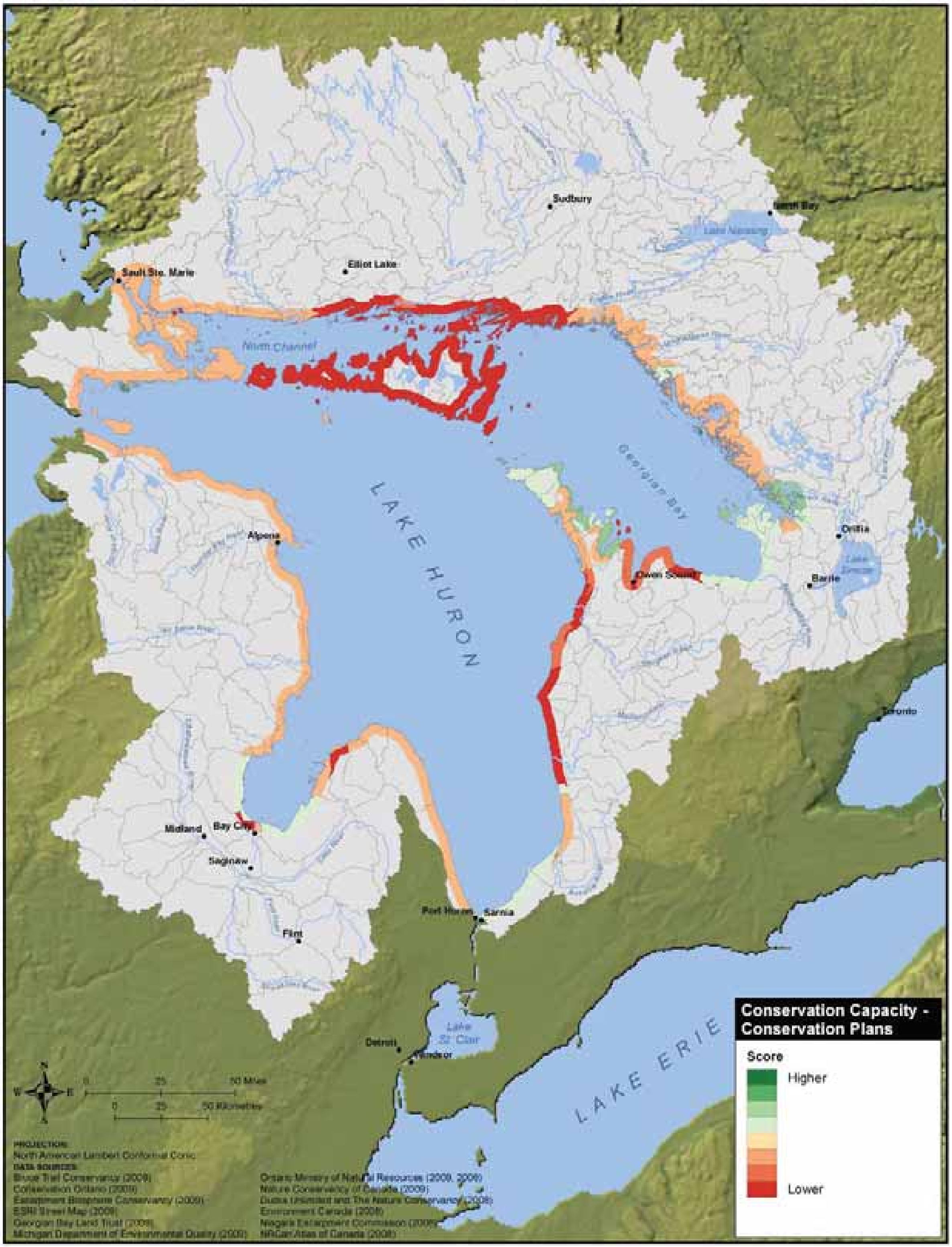

Figure 32: Conservation capacity - as measured by availability of plans - across Lake Huron.

7.1c Synthesis of priority area analysis

By synthesizing the above analysis of the coastal wetland, Coastal Terrestrial System, island and migratory bird stopover habitat biodiversity features, this project has identified priority areas for biodiversity conservation that occur throughout Lake Huron's coasts, Islands and island complexes. These are areas that have one or more biodiversity features that are significant (i.e. high scoring) within the context of Lake Huron as a whole (Figure 33). Table 29 provides a summary of the average score and range of values for the biodiversity features from each Lake Huron sub-region, and a discussion on each sub-region follows. Values are also summarized for the coastal development footprint and conservation capacity. A more detailed table summarizing this attributes for the top 100 coastal and island units can be seen in Appendix E.

Table 29: Summary of biodiversity feature values from Lake Huron regions.

Lake Huron Sub-Region	Number of Units [6]	Wetland Significance (average/ range)	Coastal Terrestrial Significance	Islands (number of priority islands/ island complexes)	Aerial Migrants (average/ range)	Coastal Development Footprint (average/ range)	Conservation Capacity (Protected Areas) (average/ range)	Conservation Capacity (Plans and Organizations) (average/ range)
Bruce Peninsula	145	**3.6**[7] 0-16	10 1-43	8	1.8 0-7	**12.7** 0-32	**6.8** 0-28	2.6 0-8
Georgian Bay	998	3.2 0-14	**11.5** 1-43	13[8]	N/A[9]	9.0 0-21	**3.9** 0-28	2.9 0-12
Manitoulin Island	313	1.0 0-11	**10.3** 0-38	45	2.8 0-7	9.9 0-23	0.2 0-14	0 0-4
North Channel	441	1.0 0-10	**10.8** 0-32	3	0.9 0-7	9.7 0-28	1.3 0-28	0.5 0-4
Nottawasaga Bay	94	**4.2** 0-14	8.9 0-34	10	1.4 0-7	**12.3** 0-40	0.7 0-14	2.0 0-8
Saginaw Bay	121	**4.6** 0-17	4.5 0-26	18	**3.2** 0-7	7.3 0-37	**4.1** 0-28	**3.4** 0-8
South Lake Huron	115	2.3 0-14	5.3 0-33	17	1.3 0-7	**13.3** 0-38	1.1 0-28	2.4 0-4
St. Mary's River	479	1.4 0-17	5.1 0-31	19	**3.2** 0-7	8.8 0-31	1.4 0-28	**3.7** 0-10
West Lake Huron	96	1.7 0-17	4.1 0-37	10	2.4 0-7	7.9 0-33	1.3 0-28	**3.5** 0-8
Lake Huron Total	*2802*	*2.3* *0-17*	*9.2* *0-43*	*122*	*2.4* *0-7*	*9.6* *0-40*	*2.5* *0-28*	*2.3* *0-12*

[6] Includes coastal units, islands and islands complexes.
[7] Boldface indicates top regional average values (75th quartile)
[8] Priority islands in Georgian Bay include several complexes that include hundreds of smaller islands.
[9] Aerial migrant analysis not done for regions on the Canadian Shield (see Figure 3)

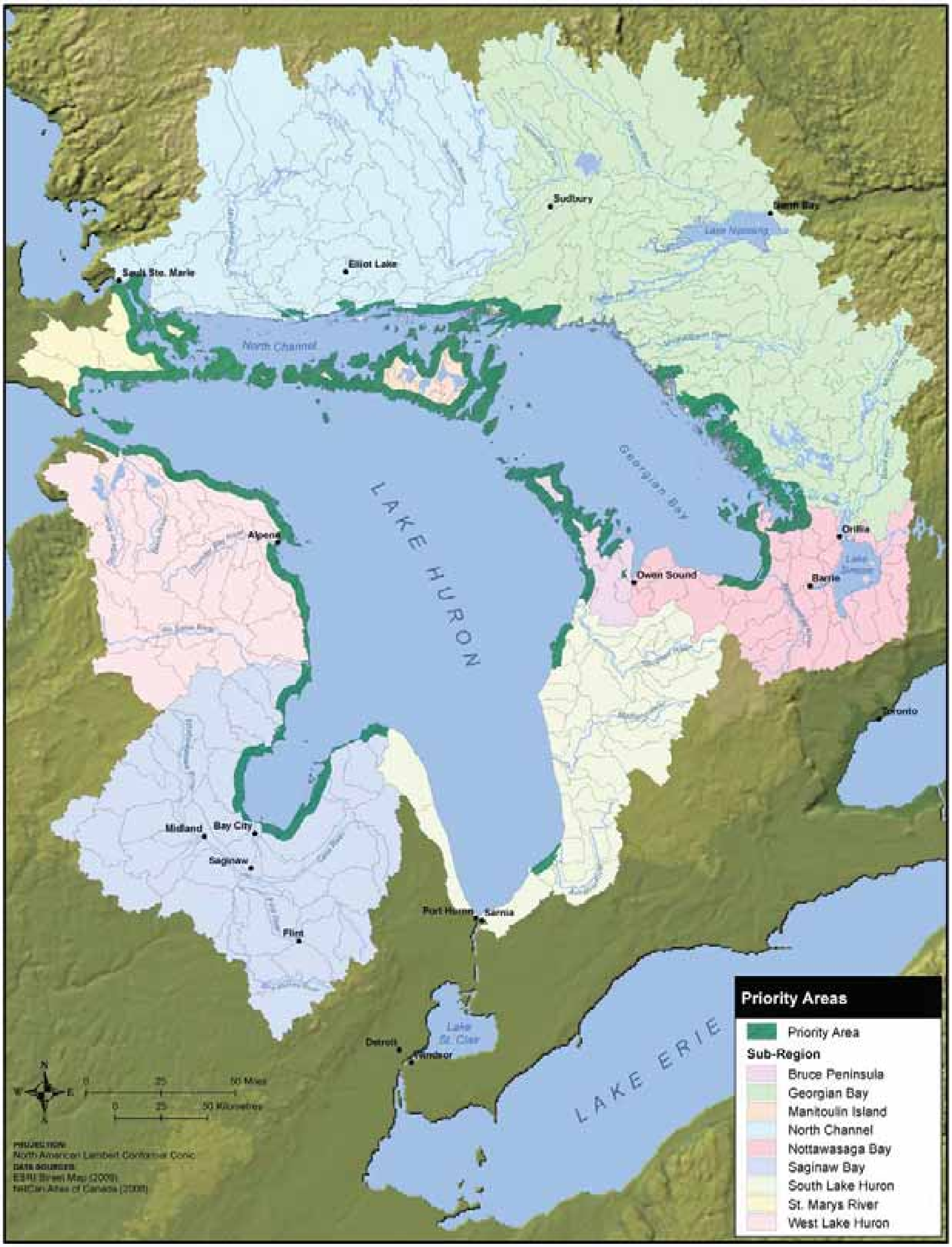

Figure 33: Priority areas by Lake Huron Sub-Region. Priority areas have one or more top scoring biodiversity features.

Bruce Peninsula

While the eastern coast of the Bruce Peninsula is dominated by spectacular cliffs associated with the Niagara Escarpment, the western coast also has a very high diversity of ecological systems including sand and cobble beaches, alvars and Coastal Wetlands. The highest scoring wetlands occur in the southwestern portion of this region (Figure 26). The Bruce Peninsula has the highest amount of forest cover compared to other areas south of the Canadian Shield, and most of the coastal areas provide high quality stop-over habitat for migrating land birds.

Most of this region has a relatively low coastal development footprint, in part because of the large number and size of protected areas, most notably Bruce Peninsula National Park. A higher coastal development footprint is associated with urban areas (i.e. Owen Sound) and the Sauble Beach area at the base of the Peninsula.

Priority Areas: western coast, Russel Island, Cove Island, Lyal Island, Hay Island, Griffin Island, Indian Island

Georgian Bay

Georgian Bay is the most complex coastal region in Lake Huron, and all of the Great Lakes. It contains the world's largest collection of freshwater Islands. While this region lacks the large Coastal Wetlands that are characteristic of the lower Great Lakes, it has thousands of smaller wetlands that combine to form some of the most extensive wetlands in Lake Huron. The Coastal Terrestrial Systems are dominated by forests and open rock barrens.

Coastal development is significantly higher in the southern portion of this region around Severn Sound. The northern section contains many roadless coastal areas with very low levels of development and many protected areas.

Priority Areas: Parry Island, Beausoleii Island, southern coastal areas

Manitoulin Island

Manitoulin Island has a very high diversity of high quality coastal ecosystems including sand beaches and dunes, alvars, cobble beaches and cliffs. Coastal Wetlands are uncommon – key wetlands occur around South Bay, Bayfield Sound and in the Misery Bay area. This region has a relatively high amount of natural land cover and most of the coastal areas provide high quality stop-over habitat for migrating land birds.

The coastal development footprint is relatively low. Manitoulin Island has very few protected areas and low conservation capacity compared to other sub-regions.

Priority Areas: southern coast (particularly in the west), Little La Cloche Island, Great La Cloche Island, Amedroz Island, Bedford Island, Clapperton Island, Fitzwilliam Island, Yeo Island, Northwest Burnt Island, Strawberry Island, Barrie Island, Vidal Island, Great Duck Island

North Channel

The North Channel extends from Espanola to Sault Ste. Marie, and is characterized by bedrock shores/ cliffs. It includes several priority areas for Coastal Wetlands and Coastal Terrestrial System features. Several coastal areas and Islands have a very high diversity of Coastal Terrestrial System values. Most of the sub-region has natural land cover.

Most of the North Channel has a relatively low coastal development footprint, with the exception of areas near Sault Ste. Marie and south of Blind River. Several Islands and coastal areas also have relatively small, but intensive coastal development. There are several large protected areas including La Cloche Provincial Park.

Priority Areas: Mississagi Delta and coast, eastern coastal areas, Aird Island, Darch Island, Innes Island

Nottawasaga Bay

Nottawasaga Bay is located in the southern-eastern part of Georgian Bay south of the Canadian Shield. The coast is characterized by bedrock (limestone) shores, cobble beaches and sands beaches and dunes. The Wasaga Beach area includes some of the largest and most extensive sand dunes in the Canadian portion of Lake Huron. Key Coastal Wetlands also occur in the Wasaga Beach area. Concentrations of high quality stopover habitat for land birds occur around Wasaga Beach, Penetanguishene Peninsula and on larger Islands.

This region includes several coastal areas that with urban centers and are heavily developed for recreation. Two former Areas of Concern (Severn Sound and Collingwood Harbour) have been delisted. Some of the coastal areas are protected in Provincial Parks.

Priority Areas: Wasaga Beach, Awenda, Beckwith Island, Christian Island, Hope Island, Sunset Point Island complex

Saginaw Bay

Saginaw Bay is located along the western coast of Lake Huron extending from the tip of the thumb to Tawas City. This region is characterized by extensive Coastal Wetlands with scattered sand beaches. The wetlands in Saginaw Bay are the largest contiguous wetland system in Lake Huron.

This region is more developed in the southern portions. Several protected areas occur in this region, particularly along the southern coast including Bay City and Sleeper State Parks.

Priority Areas: Maisou Island, Charity Island, Heisterman Island, Middle Grounds Island, Wild Fowl Bay Reef Cut, Au Gres Island, Burnt Cabin Point, North Island, Au Gres River, Big Creek

South Lake Huron

South Lake Huron extends from near Port Hope in Michigan to the base of the Bruce Peninsula. This region is characterized by sand and cobble beaches. There are few Coastal Wetlands except for the Kettle Point-Pinery area in Ontario. This area also has the most intact and largest system of sand dunes within the South Lake Huron region. Concentrations of high-quality stopover habitat for migrating land birds also occur in the Kettle Point-Pinery Area and from Port Huron north to Forestville.

Much of the coast in this region has been heavily impacted by development along the coast, including hundreds of groins in the southern portion of this region in Ontario. Typical of many developed regions along Lake Huron, there is generally more natural cover and housing density near the coast. With the exception of Pinery Provincial Park in Ontario, there are few protected areas in this region.

Priority Areas: Kettle Point-Pinery

St. Mary's River

This small region includes the watersheds that drain into the St. Mary's River and northern part of Lake Huron in the northwestern portion of the Lake Huron basin, and includes Drummond Island. This region has extensive Coastal Wetlands, particularly along the St. Mary's River and east of Saint Martin Bay. Other coastal ecosystems include cobble beaches and bedrock shores.

While this region has significant nodes of low density coastal development, there are large areas of intact coast. Even in more developed regions, roads and housing are generally limited to a narrow band along the coast. The southern section of this region has several large protected areas including Hiawatha National Forest, Sault Ste. Marie State Forest and St. Joseph Island Migratory Bird Sanctuary.

Priority Areas: Drummond Island, McKay Creek, Lime Island, Marquette Island, St. Joseph Island, Sugar Island, Neebish Island, Gogomain River, Charlotte River

West Lake Huron

This region occurs along the western coast of Lake Huron and extends from Tawas City north to Mackinaw. This region has some of the of the most significant Coastal Terrestrial System and wetland systems in Lake Huron, particularly around the Thunder Bay area. Extensive sand beaches and dunes, cobble beaches and many of Michigan's alvars occur in this region. Most of this region provide good quality stop-over habitat for migrating land birds. The coast is very complex with many smaller bays and includes dozens of Islands and island complexes.

There is less development in the northern portion of this region; however this includes a diversity of coastal land uses ranging from roadless areas, to intensive second home and aggregate land uses.

Priority Areas: Swan River, Black River, Little Black River, Thunder Bay Island, Round Island, Sulphur Island, Middle Island, Crooked Island, Round Island complex, Bois Blanc Island

7.2 Initial Analysis of Nearshore Zone

As described at the beginning of this chapter, the Nearshore Zone is the area of the lake from the shoreline to 30 m in depth. We have divided the Nearshore Zone into eight subzones that are similar in depth, temperature and their fish assemblage (workshop 3, J. Schaeffer and D. Reid, pers. comm.). To provide an initial review of priority areas in the Nearshore Zone, we have mapped key features within each subzone that suggest where areas of importance may be (Figures 34-41). These include Coastal Wetlands (Great Lakes Coastal Wetland Consortium 2004, OMNR 2006b, and Chow-Fraser 2009), which are important spawning and rearing habitat, accessible rivers, and potential spawning areas for lake trout and whitefish as documented in the Great Lakes GIS (2007). The potential spawning areas warrant further investigation and we recommend that they be sampled in a comprehensive way.

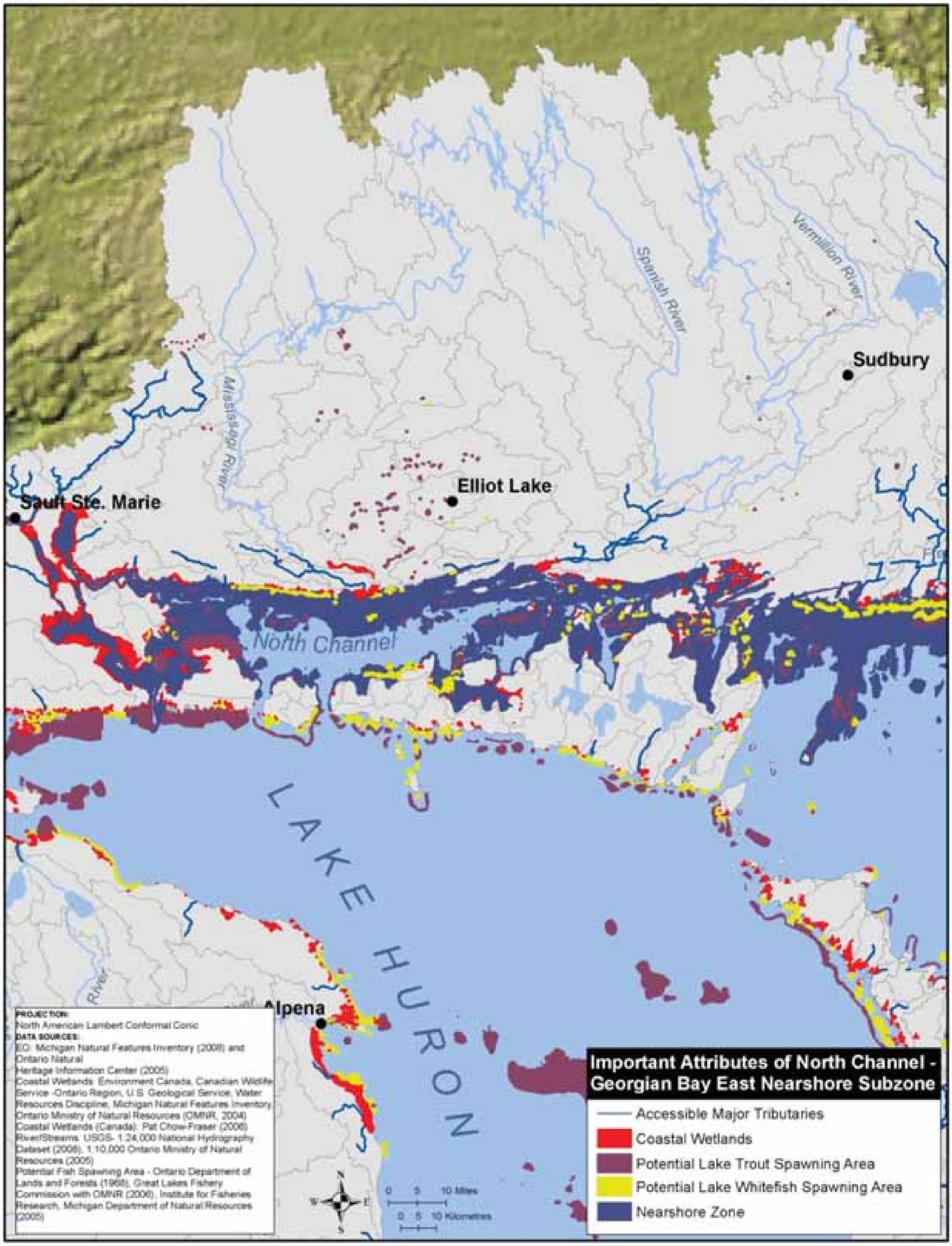

Figure 34: Ecologically significant Nearshore Zones of North Channel - Georgian Bay East.

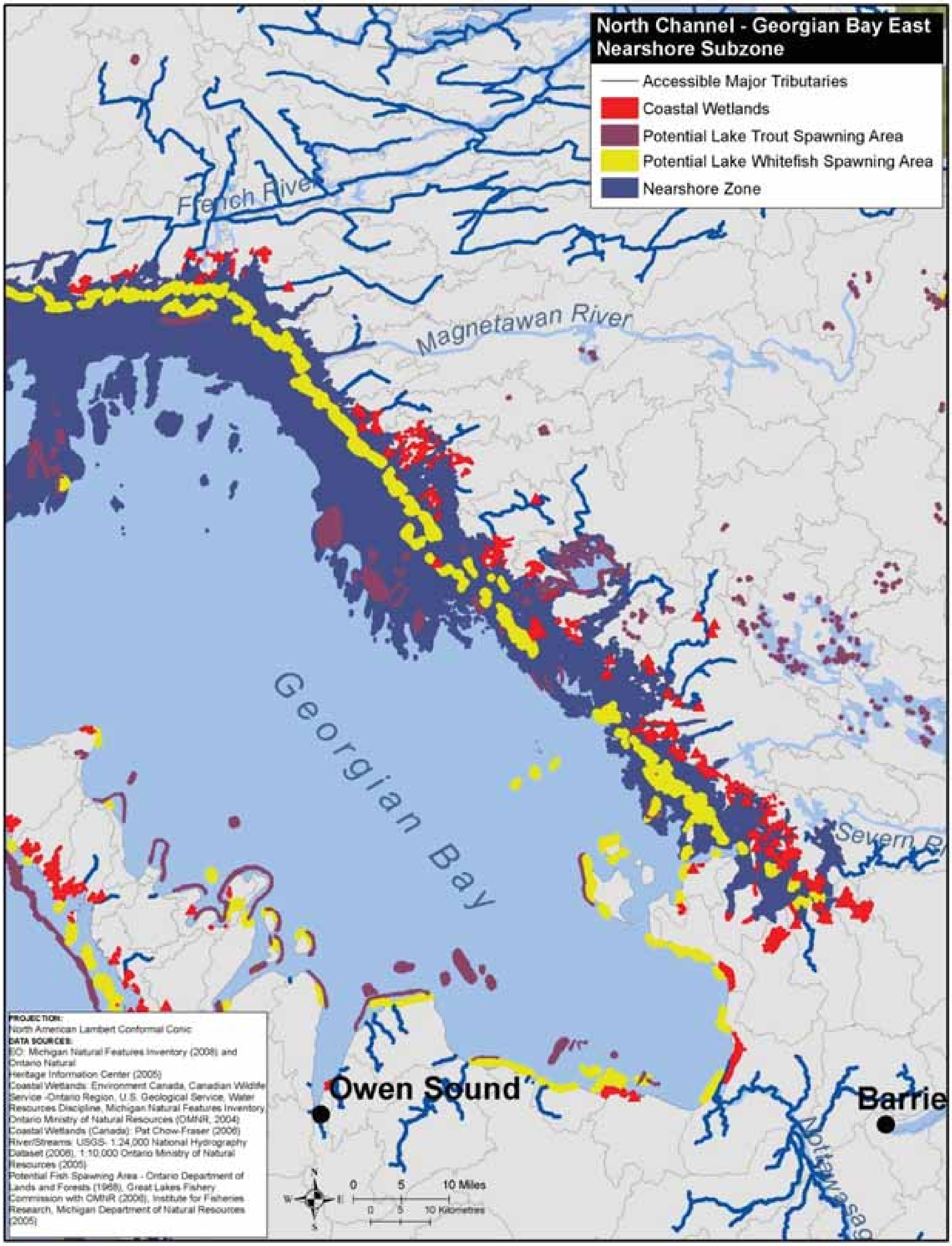

Figure 35: Ecologically significant Nearshore Zones in North Channel - Georgian Bay East.

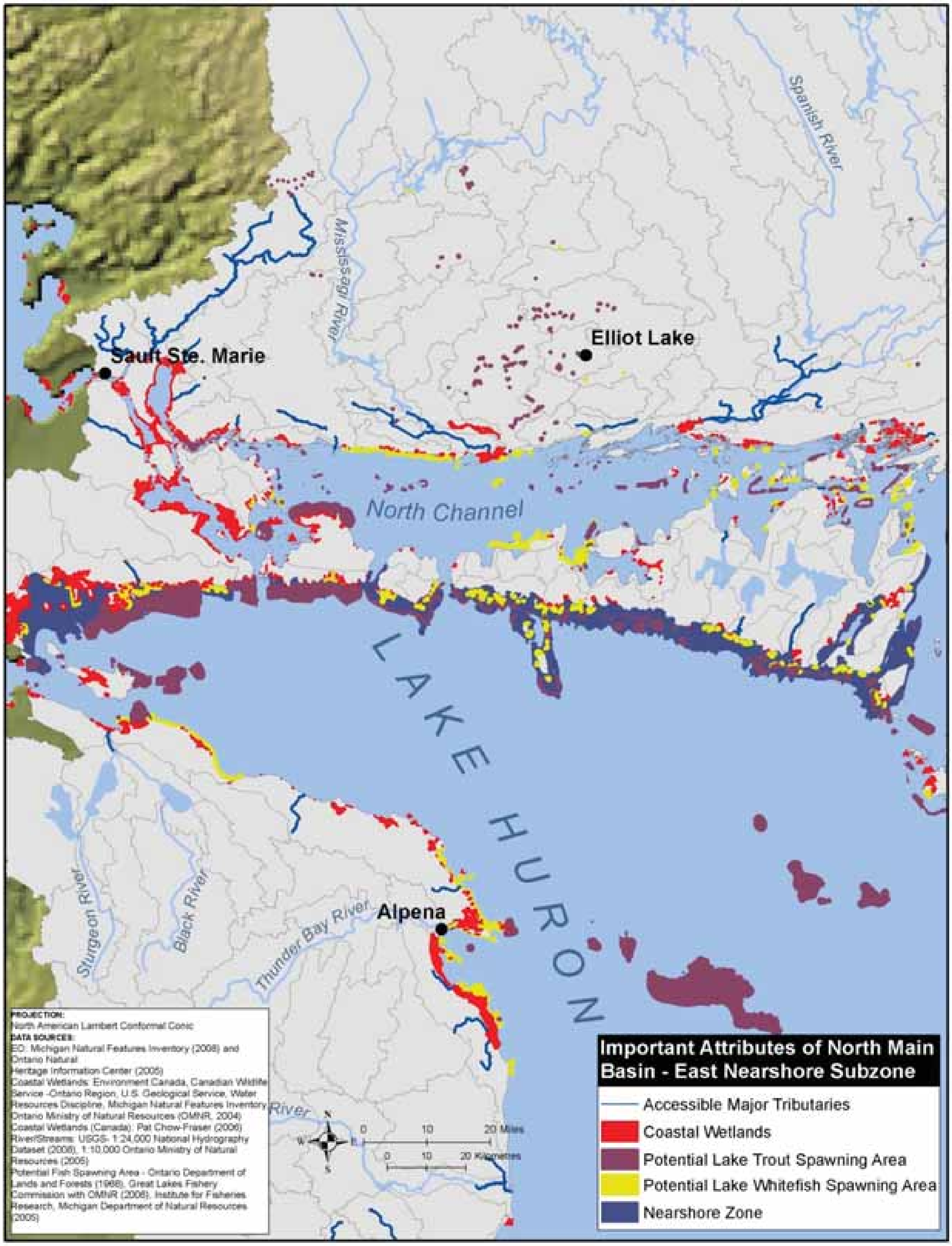

Figure 36: Ecologically significant Nearshore Zones in North Main Basin - East.

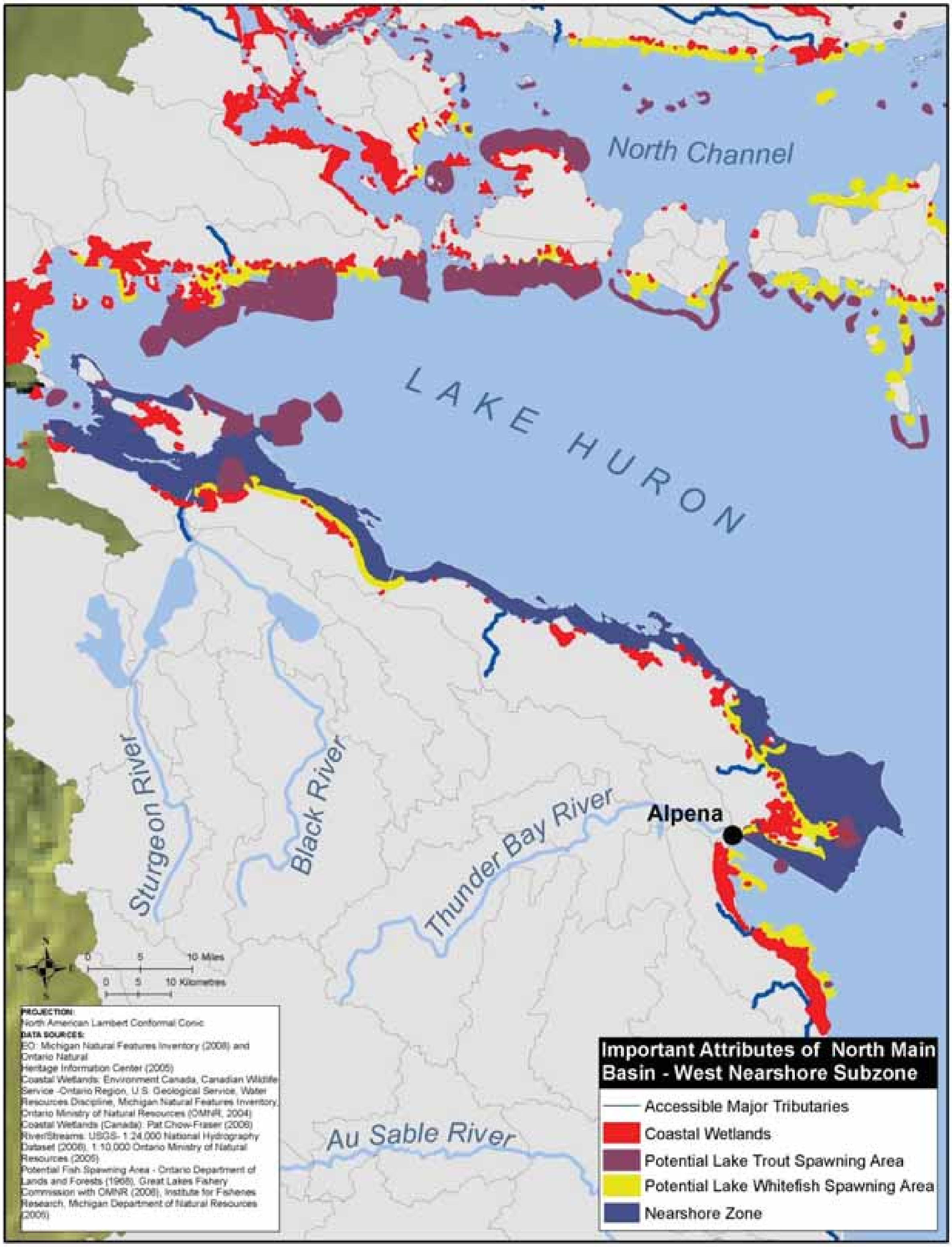

Figure 37: Ecologically significant Nearshore Zones in North Main Basin - West.

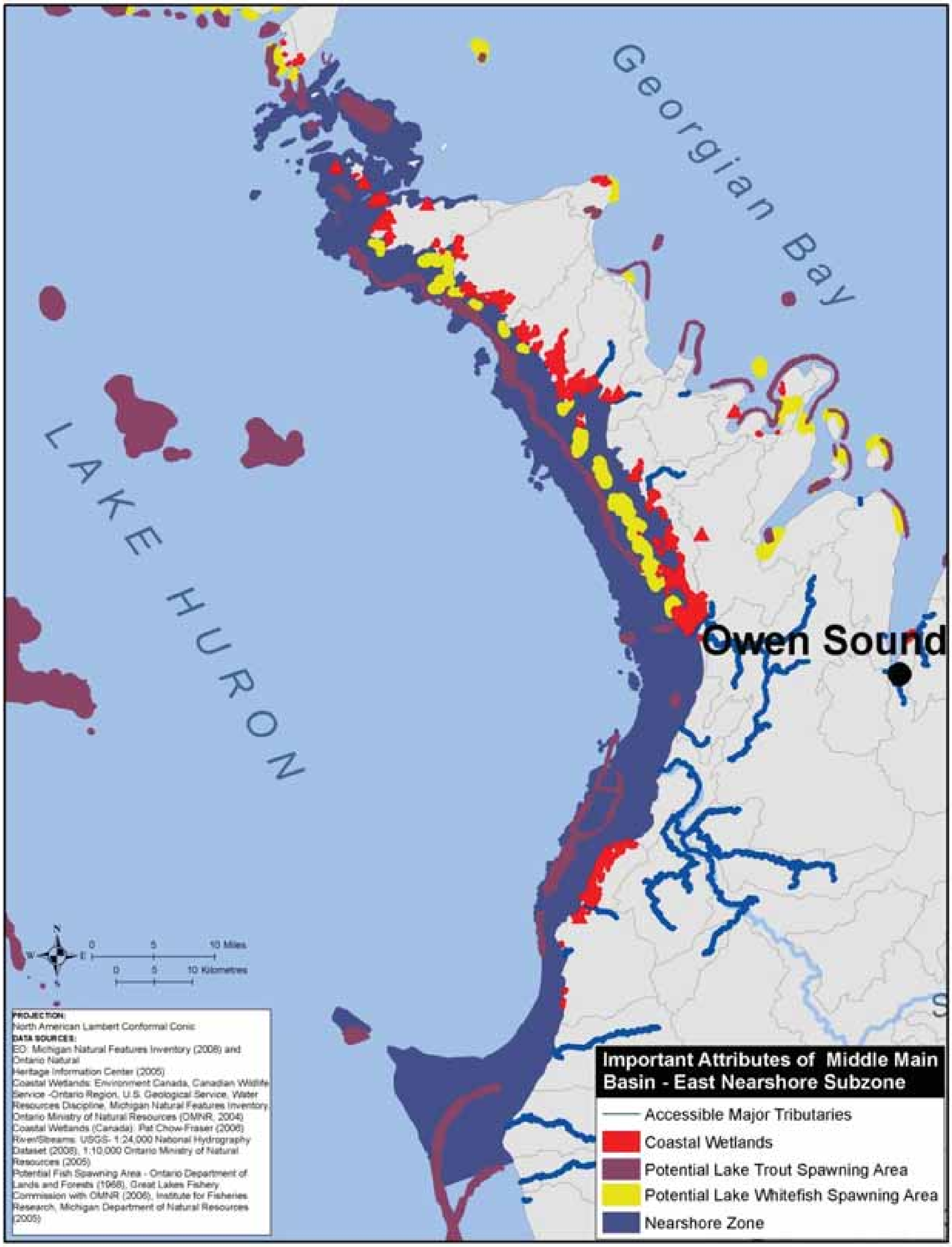

Figure 38: Ecologically significant Nearshore Zones in Middle Main Basin - East.

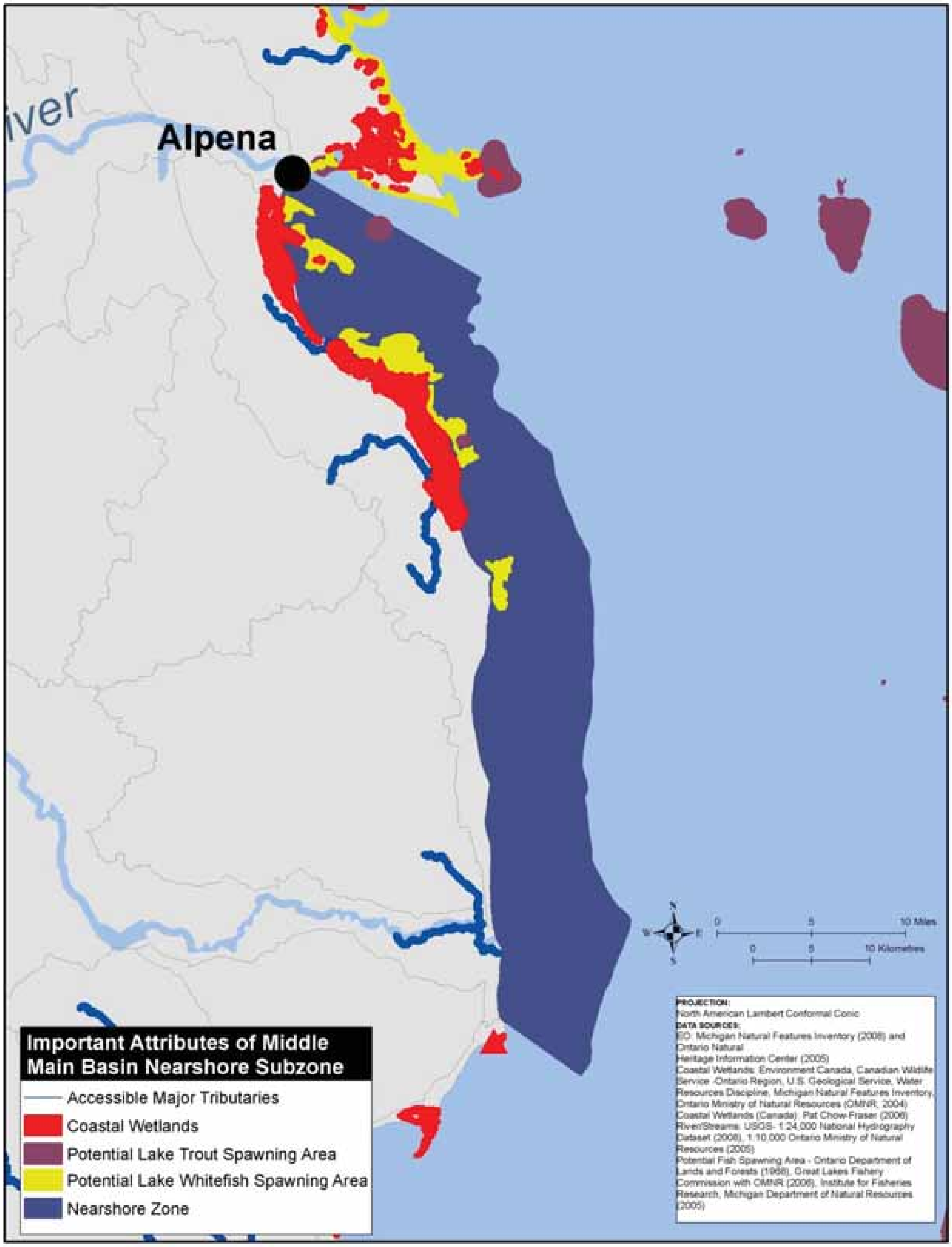

Figure 39: Ecologically significant Nearshore Zones in Middle Main Basin.

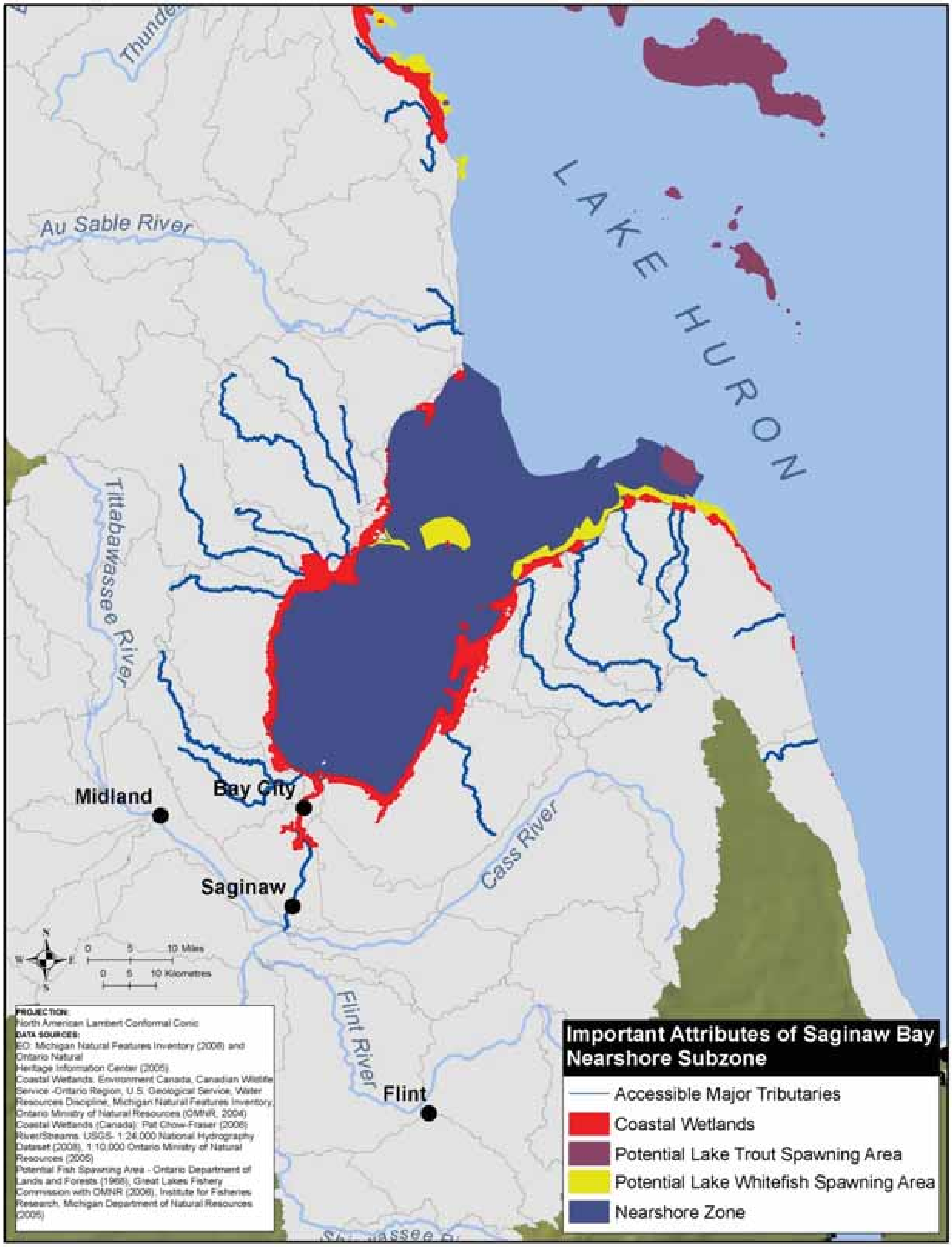

Figure 40: Ecologically significant Nearshore Zones of Saginaw Bay.

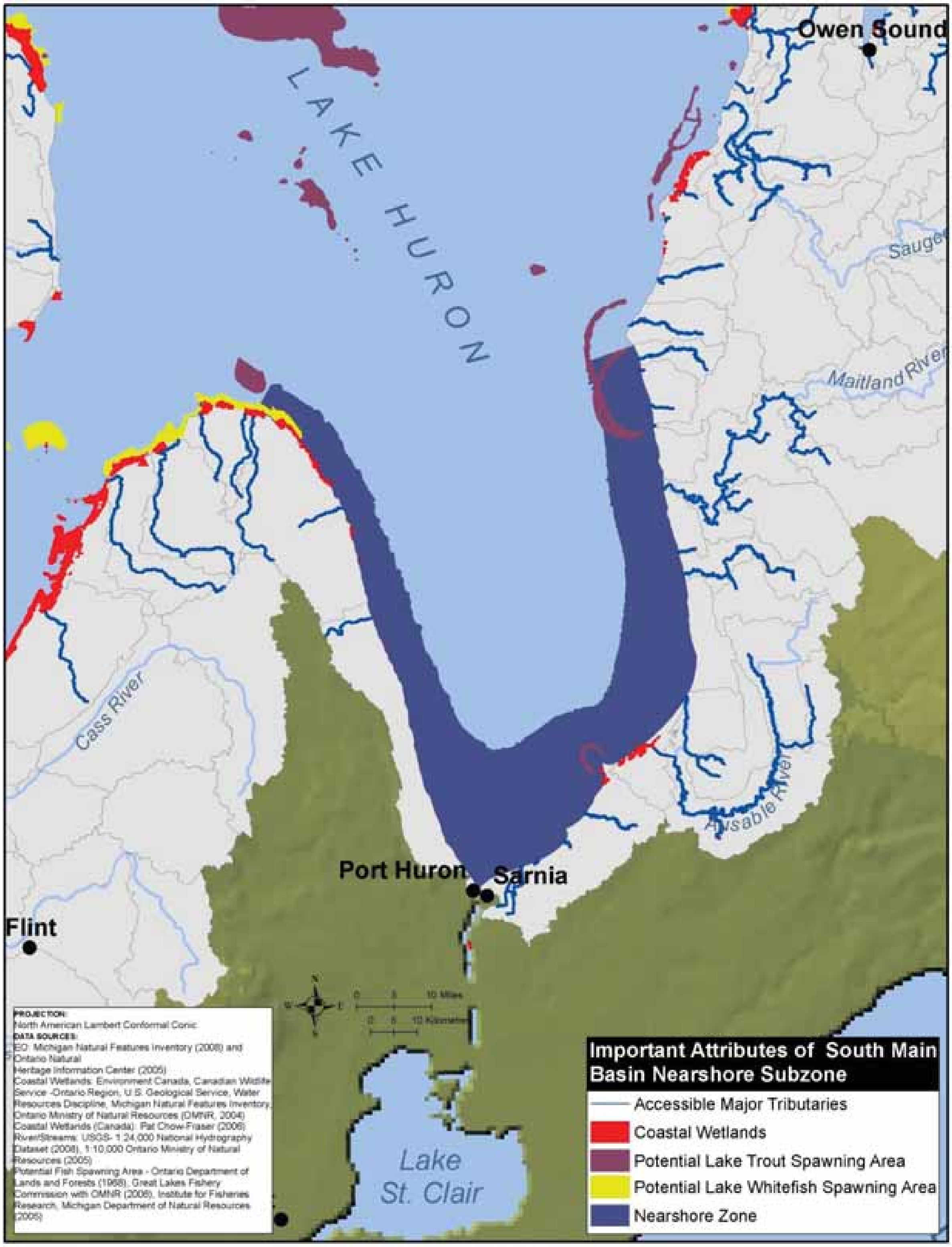

Figure 41: Ecologically significant Nearshore Zones in South Main Basin.

7.3 Conclusions

From the priority areas analysis, we have the following observations and recommendations:

- While clear areas of biodiversity significance stand out for particular features, each subregion has significant biodiversity. In addition, the three sets of maps – biodiversity significance, condition and conservation capacity do not correlate. Thus the conservation challenge and Strategy implementation implications for Lake Huron are quite complex.

- In some areas of high biodiversity significance (see Figure 33), application of land protection strategies is warranted. Biodiversity significance does not however take the goal of representation into account. Thus, we also need to include in a protection plan those areas of biodiversity significance in very developed areas.

- The priority biodiversity conservation areas identified in this chapter are a subset of the areas where conservation action must be taken; many of the strategies described in Chapter 6 are threat abatement actions that may impact conservation targets from considerable distance.

- Conservation capacity does not necessarily match the areas of highest biodiversity significance, thus we need to think beyond local conservation needs and consider how to best use those resources to abate human impacts that have a cumulative impact on the health of the whole lake ecosystem.

- Information generated for this project can be used to identify and refine local and regional priorities for conservation actions.

- We need to invest in inventory, classification and analysis of the Nearshore Zone.

8. NEXT STEPS: IMPLEMENTING STRATEGIES AND TRACKING PROGRESS

Completion of the Lake Huron Biodiversity Conservation Strategy (LHBCS) signals a commitment to advance protection efforts that maintain and restore the ***chemical, physical, and biological integrity*** of the aquatic and Coastal Terrestrial Systems of Lake Huron. The LHBCS represents a framework for biodiversity conservation and a keystone piece that will guide implementation actions that mitigate critical threats to the native biological diversity of Lake Huron. By recommending biodiversity conservation actions, the LHBCS addresses a previously an unmet gap; yet it is supported by and related to a number of other plans and strategies for Lake Huron. The biodiversity perspective contained within this document can inform current decisions and future plans.

8.1 Guiding Implementation Principles

Several recurrent themes and principles emerged throughout the course of developing the LHBCS that can guide implementation of its recommendations.

8.1.a Adaptive Management

Adaptive management is an increasingly employed management paradigm, particularly when addressing large, complex ecological systems like Lake Huron. This approach is inherent in the Conservation Action Planning (CAP) process applied throughout the development of the LHBCS (Figure 2). It enables decision-makers and practitioners to be proactive in identifying and undertaking the necessary conservation actions to restore degraded conservation features or prevent irreversible damage. Use of indicators to monitor outcomes can give managers a timely understanding of effectiveness and allow for modifications of their approaches. Monitoring at various geographic and time scales and linking results back to improvements in biodiversity feature viability can also advance scientific understanding of these dynamic ecosystems, and improve our ability to anticipate ecological response earlier in the Strategy development and implementation process.

8.1.b Habitat Protection and Restoration

Several features such as Islands, Coastal Wetlands, Nearshore Zone, and terrestrial habitats are in excellent condition in parts of the Lake Huron basin and should remain so given the need for representative, functional habitats that can act as refugia from changing land use and climate. However, protective habitat management should be balanced with habitat restoration as part of integrated resource management programs.

8.1.c Integration and Cooperation

Incorporation of the LHBCS recommendations into existing management programs is one potential avenue for their implementation. Doing so will foster cooperation and alignment of biodiversity conservation activities across political, environmental, social and economic boundaries. The LHBCS forms the basis of a harmonized, international approach to biodiversity conservation.

8.1.d Geographic Variability

The Lake Huron basin is extremely variable in terms of land use, water chemistry, geology, bathymetry, shoreline configuration, regional climate, and ecological condition. For example, the Georgian Bay watershed has a much higher percent of natural vegetation coverage than most of the rest of the watershed; shorelines of the main basin are exposed to much higher wind and wave energy than this area and most of the larger settlements are on the main basin.

While some strategies can be implemented on a basin-wide scale, others are more appropriate for regional and local implementation that can take these specialized conditions and circumstances into consideration. In addition to these biogeochemical variations, there are also substantial cultural, political, and economic perspectives that must also be understood and accounted for in implementation. For example, integrated watershed management plans also follow an adaptive management approach and provide a relevant scale for the modeling of watershed responses to various land use and climate change scenarios and examining the interrelationship with nearshore response can be examined and management decisions adjusted accordingly.

8.1.e Awareness, Capacity Building, Education, and Shared Responsibility

A conservation ethic will emerge through an aware and engaged public. Thus, connecting people with Lake Huron biodiversity conservation issues and solutions will provide a key motivating force among decision-makers for broad-scale implementation of the LHBCS recommendations. To manage the lake and its watershed in a sustainable way, working relationships that connect individuals, communities and governments should be encouraged and promoted.

8.2 Recognizing and Overcoming Barriers

Undertaking the task of conserving Lake Huron's biodiversity is a long-term, multi-faceted endeavor that will require commitment and collaboration across multiple sectors. Identifying and understanding potential obstacles is a necessary precursor for overcoming them, and the following are some cautions about real and perceived barriers to biodiversity conservation gleaned throughout the LHBCS process.

8.2a Gaps in Research and Understanding

Despite a high concentration of academic and governmental research institutions in southern Ontario and Michigan, significant knowledge gaps persist related to food web changes, recent nutrient trends and underlying mechanisms, Nearshore Zone processes, cumulative and interactive effects, and climate change scenarios and consequences. Even basic information and datasets are lacking on current environmental condition and trends, and, in some cases, extent and condition of selected biodiversity conservation features. For example, we lack information on the distribution of fish species and their habitat in Nearshore Zones; we even lack good maps of spawning shoals in the lake. Without credible scientific information, the development of strategies and their implementation are constrained.

Key research and monitoring recommendations that will facilitate implementation of the LHBCS include the following:

- When properly supported, scientific research efforts can provide the information and technology necessary to maintain and improve management decisions regarding biodiversity conservation for Lake Huron.

- Basic information such as Nearshore Zone bathymetry, substrate, physical processes, aquatic communities, and human uses would be most useful if collected in a spatially-explicit and easily accessible format for decision-makers.

- Climate-related impacts and cumulative effects could be modeled at various scales and incorporated into a spatially-explicit decision support system to inform management decisions and support implementation.

- Biodiversity research gaps could be shared with and among management agencies and academic programs to facilitate their integration into lake-based research priorities and programs, including:
    - The LHBP organizes symposia and workshops to share and discuss science needs for the lake, as well as creating five-year work plans inclusive of research efforts.
    - The GLFC's Lake Huron Technical Committee articulates research needs as they support their fisheries management mandate.
    - The Cooperative Science and Monitoring Initiative's Science Committee integrates and coordinates binational environmental monitoring and research networks and programs on a five-year cycle.
    - Academic institutions have graduate students seeking innovative, applied science studies that may inform management decisions.

- Aquatic and Coastal Terrestrial System research can address Lake Huron environmental management needs, goals, and objectives and reflect the contributions of its partners in data and knowledge generation. Partnerships outside the LHBP might also be pursued, including academia, Aboriginal and Tribal groups, industry, non-governmental organizations, and other government agencies.

- Existing non-point source pollution Best Management Practices (BMPs), restoration techniques, and invasive species prevention detection and response techniques could be evaluated for their effectiveness and new, innovative technologies developed as needed.

8.2b Implementation & Governance

The immense scale and ecological complexity of Lake Huron, as well as the sheer number of strategies contained in the LHBCS represent significant implementation challenges. No single entity can implement all conservation strategies, as those responsibilities are shared among the numerous management agencies.

More local implementation and investment will be necessary for many of the recommended strategies; however, conflicting land/water use interests and objectives present a significant implementation barrier. For example, when dam decommissioning is proposed, residents may value the reservoir for recreation and have less appreciation for the ecological benefits of dam removal. Another illustration is shoreline management, where population sprawl and development may take precedence over coastal conservation.

Recommendations:

- LHBCS implementation can be advanced by identifying existing governance frameworks and synergies with programs that have complementary goals and objectives. A collaborative and cooperative management approach should be used where possible to meet multiple and coinciding missions and mandates.

- The LHBP is recognized as the principal mechanism for binational planning, coordination, and reporting in support of the GLWQA and overall restoration, protection, and maintenance of the aquatic ecosystem of Lake Huron, and is recommended as the mechanism for tracking progress toward LHBCS implementation and measuring successes.

- Implementation of the LHBCS recommendations will benefit from the participation of all conservation entities around the basin, therefore establishing innovative partnerships that draw on the expertise and perspective of public agencies (at the federal, state/provincial, and regional/local levels, including Conservation Authorities), environmental non-governmental organizations, local stewardship groups, foundations, corporations, and other private entities will build on, support, and enhance existing restoration, management, research, land protection, and stewardship efforts.

- Issue- or task-oriented technical working groups may be a successful mechanism for implementing the LHBCS without supplementing or supplanting the many existing governance structures; these working groups could tap key natural resource managers, scientists, or existing lake-based working groups to address specific biodiversity conservation issues, strategies, and technical guidance needs.

- Existing collaborative initiatives (e.g. South Georgian Bay) may be in the best position to advance the recommended strategic actions; sharing lessons learned throughout the basin will assist others with implementation.

8.2c Monitoring Trends, Tracking Conservation Success, and Reporting

The large size, ecological complexity, and the dynamic interactions between Lake Huron and the surrounding watershed represent significant challenges to monitoring environmental conditions and tracking the success of biodiversity conservation. While numerous government, academic, and private scientists study Lake Huron's aquatic ecosystems, natural communities, and species, a comprehensive suite of international indicators and standardized methodologies to monitor spatial and temporal trends of key ecosystem components has not been established for Lake Huron.

Recommendations:

- Establishing a suite of harmonized, binational indicators could provide the basis for tracking the status and trends of selected conservation features and nested features throughout the basin.

- Existing Lake Huron programs should coordinate on how to incorporate and meet biodiversity research, monitoring, indicator development, and reporting needs.

- Monitoring should be given sufficient, sustainable, and dedicated resources.

- Monitoring, tracking, and reporting on LHBCS implementation can occur at multiple scales and take several forms, including programmatic metrics (i.e. what conservation actions have been taken), biodiversity status and trends by watershed, and ecosystem response to mitigation measures. Reporting could be integrated into existing basin-wide monitoring and tracking efforts, and be compared against desired conditions articulated for the biodiversity conservation features' long-term viability (Chapter 4: Viability Assessment).

8.2d Building Awareness, Capacity, and Conservation Partnerships

As mentioned above, increased awareness and public engagement are two necessary enabling conditions for LHBCS implementation. Not only can the public directly participate in implementation, they can also help foster political will to act at the needed scale to conserve Lake Huron's biodiversity.

Recommendations:

- Public awareness of Lake Huron's biodiversity conservation issues and challenges can be increased through awareness strategies that provide additional education opportunities and forum for discussion, including websites, summits, volunteer work days, and materials that make the findings of the LHBCS more accessible to a lay audience (e.g. Biodiversity Atlas). Ecosystem goods and services that biodiversity provides are a useful message for improving understanding of a healthy Lake Huron ecosystem.

- In order for LHBCS implementation to be successful, community values and interests should be understood and addressed; the threat-based conceptual models are a first step in appreciating these circumstances, but similar analyses can be done at the appropriate scale of implementation.

- Guidance should be provided to potential implementation partners and researchers who want to incorporate Lake Huron biodiversity conservation priorities into their work plans.

- Promoting principles of sustainability would enable individuals and communities to support biodiversity conservation actions. Where feasible and appropriate, strategies should be translated into actions the public can participate in; local participation in the implementation process should be encouraged.

8.2e Financing Biodiversity Conservation

Financing the conservation and sustainable use of biodiversity has been recognized as one of the greatest challenges. At the heart of this challenge lies the low financial and political value that is often assigned to biodiversity and the resulting lack of financial mechanisms for conservation and sustainable use. These values are often underrepresented.

Recommendations:

- Because resources are finite, current programs can be more strategic and coordinated within and among themselves to ensure meaningful and substantive results; initiatives that provide an opportunity to integrate and address municipal, watershed, provincial or state and federal priorities and objectives should be a high priority for resources.

- Biodiversity conservation is relatively new language to Great Lakes management, and conservation needs and priorities must be clearly articulated. Clear lines of communication are needed to both understand how biodiversity conservation objectives are being advanced by complementary, or even seemingly unrelated, programs; frequent, clear communication will also reveal biodiversity conservation objectives that are yet unmet. Communicating overlapping priorities and critical gaps will allow for a more frank discussion of priorities for existing funding mechanisms to account for broader conservation priorities.

- A sourcebook of financing mechanisms could be developed to provide a clearinghouse of financing mechanisms that can be matched with biodiversity conservation activities.

- Each agency and organization has different funding sources and opportunities available to them and by creating diverse, cross-sector partnerships, more funding can be leveraged to increase the overall available funding for the LHBCS recommendations. These partnerships could not only improve the deployment and operation of long-standing programs, but would also position Lake Huron stakeholders to respond to new opportunities as they emerge (e.g. Great Lakes Restoration Initiative).

9. CONCLUSION/CALL TO ACTION

The maintenance and protection of the biological integrity of the Great Lakes is a cornerstone of the Great Lakes Water Quality Agreement. **The Lake Huron Biodiversity Conservation Strategy** represents a unifying vision to improve collaboration and advance integrated, cross-boundary ecosystem management for Lake Huron. It is the result of over two years of stakeholder consultation, solicitation of expert opinions, and integration of existing biodiversity conservation data, program goals, and objectives.

These efforts resulted in the identification of key biodiversity conservation features for planning and conservation focus, their current condition, critical threats and contributing factors, recommended actions to mitigate threats, and priority coastal regions and watersheds that should be the focus for implementation of protection activities. The LHBCS also provides a lakewide biodiversity context that will assist in land-use and conservation decisions, and serve to inform the general public of the importance of biodiversity conservation.

It is recognized that given the enormous scale and complexity of the Lake Huron basin, and the range of recommended biodiversity conservation strategies, the key to success lies in cooperative partnerships and stakeholder engagement throughout the basin. The strategies and actions outlined in this report are offered as a guide to the protection and restoration of Lake Huron's biodiversity.

In addition to suggested actions and areas for biodiversity conservation, the LHBCS references ongoing efforts that can serve as examples for initiating implementation at various scales (Chapter 6.3, 'Opportunity Areas for Implementation' listed under each strategy), includes a list of active individuals and entities (Appendix B), and highlights related plans, initiatives, and agreements that note possible entry points for implementation (especially the 'Lake Huron Binational Partnership 2008-2010 Action Plan' (Lake Huron Binational Partnership, 2008) which inventories many significant efforts already underway).

But the LHBCS is just the beginning of an urgent and important journey, and this first step will only be as meaningful as potential implementers make it through their actions. Through this process, participants have expressed commitments to integrate these findings into local strategic planning efforts, providing a bridge from the broad, basin-wide scale to action in their own backyards. Participants have voiced a desire and need to continue this valuable dialogue and update these recommendations as conservation successes are realized and perhaps new challenges emerge. Finally, participants have underscored the enormity and urgency of the conservation charge herein. Achieving lasting conservation of Lake Huron's biodiversity requires the ongoing attention and action of everyone that has participated in this process, and many more.

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Appendices

Appendix A
Glossary

Adaptive Management – A process originally developed to manage natural resources in large scale ecosystems by deliberate experimentation and systematic monitoring of the results. More broadly, it is the incorporation of a formal learning process into conservation action. Specifically, it is the integration of design, management, and monitoring to systematically test assumptions in order to learn and adapt.

Biological diversity, or **biodiversity**, refers to the variety of life, as expressed through genes, species, interactions and ecosystems, and is shaped by ecological and evolutionary processes. The full spectrum of biodiversity is essential to maintaining the ecological functions, processes and connections that sustain us and provides many economic and social benefits.

CAP – Shorthand for Conservation Action Planning.

Conservation Action Planning (CAP) – The Nature Conservancy's process for helping conservation practitioners develop strategies, take action, measure success, and adapt and learn over time.

Conservation Project – A set of strategies taken by a defined group of practitioners working to achieve specific conservation goals and objectives for a set of conservation targets. A project can range in scale from managing a small site over a few weeks to an entire region over many years.

Contribution – One of the criteria used to rate the impact of a source of stress. The degree to which a source of stress, acting alone, is likely to be responsible for the full expression of a stress within the project area within 10 years.

Critical Threats – Sources of stress (direct threats) that are most problematic.

Current Status – An assessment of the current "health" of a target as expressed through the most recent measurement or rating of an indicator for a key ecological attribute.

Degraded Attribute – A key ecological attribute that is outside its acceptable range of variation.

Desired Status – A measurement or rating of an indicator for a key ecological attribute that describes the level of viability/integrity that the project intends to achieve. Generally equivalent to a project goal.

Direct Threats – Used as a synonym for sources of stress. Agents or factors that directly degrade targets. A project's highest ranked direct threats are its critical threats. For example, "logging" or "fishing."

Focal Conservation Features – A limited suite of species, communities, and ecological systems that are chosen to represent and encompass the full array of biodiversity found in a project area. They are the basis for setting goals, carrying out conservation actions, and measuring conservation effectiveness. In theory, conservation of the focal targets will ensure the conservation of all native biodiversity within functional landscapes.

Goal – The desired summary status of a focal conservation target. Generally will be a "good" or "very good" viability rating for the target.
Indicators – Measurable entities related to a specific information need (for example, the status of a key ecological attribute, change in a threat, or progress towards an objective). A good indicator meets the criteria of being: measurable, precise, consistent, and sensitive.

Indirect Threats – Contributing factors identified in an analysis of the project situation that are drivers of direct threats. Often an entry point for conservation actions. For example, "logging policies" or "demand for fish."

Integrity – The status or "health" of an ecological community or system. Integrity indicates the ability of a community or system target to withstand or recover from most natural or anthropogenic disturbances and thus to persist for many generations or over long time periods.

Irreversibility – One of the criteria used to rate the impact of a source of stress. The degree to which the effects of a source of stress can be restored or recovered. Typically includes an assessment of both the technical difficulty and the economic and/or social cost of restoration.

KEA – Short for Key Ecological Attribute.

Key Ecological Attributes (also Key Attributes, or KEAs) – Aspects of a target's biology or ecology that, if missing or altered, would lead to the loss of that target over time. As such, KEAs define the target's viability or integrity. More technically, the most critical components of biological composition, structure, interactions and processes, environmental regimes, and landscape configuration that sustain a target's viability or ecological integrity over space and time.

Nested Features – Species, ecological communities, or ecological system targets whose conservation needs are subsumed in one or more focal conservation targets. Often includes targets identified as ecoregional targets.

Objectives – Specific statements detailing the desired accomplishments or outcomes of a particular set of activities within a project. A typical project will have multiple objectives. Objectives are typically set for abatement of critical threats and for restoration of degraded key ecological attributes. They can also be set, however, for the outcomes of specific conservation actions, or the acquisition of project resources. If the project is well conceptualized and designed, realization of all the project's objectives should lead to the fulfillment of the project's vision. A good objective meets the criteria of being: specific, measurable, achievable, relevant, and time limited.

Opportunities – Contributing factors identified in an analysis of the project situation that potentially have a positive effect on targets, either directly or indirectly. Often an entry point for conservation actions. For example, "demand for sustainably harvested timber."

Project Area or Project Scope – The place where the biodiversity of interest to the project is located. It can include one or more "conservation areas" or "areas of biodiversity significance" as identified through ecoregional assessments. Note that in some cases, project actions may take place outside of the defined project area.

Scope (in the context of a threat assessment) – One of the measurements used to rate the impact of a stress. Most commonly defined spatially as the proportion of the overall area of a project site or target occurrence likely to be affected by a threat within 10 years.

Severity – One of the criteria used to rate the impact of a stress. The level of damage to the conservation target that can reasonably be expected within 10 years under current circumstances (i.e., given the continuation of the existing situation).

Sources of Stress – The proximate activities or processes that directly have caused, are causing, or may cause stresses and thus the destruction, degradation and/or impairment of focal conservation targets. Synonymous with direct threats
.

Stakeholders – Individuals, groups, or institutions who have a vested interest in the natural resources of the project area and/or who potentially will be affected by project activities and have something to gain or lose if conditions change or stay the same.

Status Assessment Measures – Information used to answer the questions: "How is the biodiversity we care about doing?", "How are threats to biodiversity changing?", or
"How is the conservation management status changing?" Answers to these questions, even when no actions are occurring, are important to determine if actions are needed. Compare to strategy effectiveness measures.

Strategic Actions – Interventions undertaken by project staff and/or partners designed to reach the project's objectives. A good action meets the criteria of being: linked to objectives, focused, strategic, feasible, and appropriate.

Strategies – Broad courses of action that include one or more objectives, the strategic actions required to accomplish each objective, and the specific action steps required to complete each strategic action.

Strategy Effectiveness Measures – Information used to answer the question: Are the conservation actions we are taking achieving their desired results? Compare to status assessment measures.

Stresses – Impaired aspects of conservation targets that result directly or indirectly from human activities (e.g., low population size, reduced extent of forest system; reduced river flows; increased sedimentation; lowered groundwater table level). Generally equivalent to degraded key ecological attributes (e.g., habitat loss).

Features – Elements of biodiversity which can include species, ecological communities, and ecological systems. Strictly speaking, refers to all biodiversity elements at a project site, but sometimes is used as shorthand for focal conservation features.

Threats – Agents or factors that directly or indirectly degrade targets. See also direct threat, indirect threat, and critical threat.

Viability – The status or "health" of a population of a specific plant or animal species. More generally, viability indicates the ability of a conservation target to withstand or recover from most natural or anthropogenic disturbances and thus to persist for many generations or over long time periods. Technically, the term "integrity" should be used for ecological communities and ecological systems with “viability” being reserved for populations and species. In the interest of simplicity, however, we use viability as the generic term for all targets.

Vision – A general summary of the desired state or ultimate condition of the project area or scope that a project is working to achieve. A good vision statement meets the criteria of being relatively general, visionary and brief. For most biodiversity conservation projects, the vision will describe the desired state of the biodiversity of the project area.

Appendix B
Participant List

The following table is a list of individuals and their organizations that participated in the Lake Huron Biodiversity Conservation Strategy. This list includes individuals who completed the survey and/or attended one or more workshops.

First Name	Last Name	Organization
Chief Craig	Abotossaway	Aundeck Omni Kaning
Charles	Adams	Sault Ste Marie Tribe of Chippewa Indians
Rex	Ainslie	Michigan Department of Natural Resources (DNR)
Chief Ralph	Akiwenzie	Saugeen First Nation
Dennis	Albert	Michigan Natural Features Inventory
Sandra	Albert	Anishnabek Nation (Union Of Ontario Indians)
Dave	Allan	University of Michigan
Dave	Anderson	Ontario Ministry of Natural Resources (OMNR)
Janette	Anderson	Environment Canada
Muriel	Andreae	St. Clair Region Conservation Authority
Andrea	Ania	US Fish and Wildlife Service
Ryan	Archer	Bird Studies Canada
Madeline	Austen	Environment Canada - CWS-SAR Lead
Peter	Badra	Michigan Natural Features Inventory (MNFI)
Sarah	Bailey	Department of Fisheries and Oceans
Tom	Bailey	Little Traverse Conservancy
Jim	Baker	Michigan DNR Fisheries
Robert	Baldwin	Lake Simcoe Region Conservation Authority
Charles	Bauer	MDEQ Water Bureau
Chief Isadora	Bebamash	M’Chigeeng First Nation, Anishinabek Women's Water Commission
Jim	Bence	Michigan State University
Bopaiah	Bidanda	Annis Water Resources Insititute, Grand Valley State University
Chief Donna	Bigcanoe	Chippewas of Georgina Island First Nation
Chief Alfred	Bisaillon	Thessalon First Nation
John	Bittorf	Grey Sauble Conservation
Ron	Black	Ontario Ministry of Natural Resources
Jim	Boase	US Fish and Wildlife Service
Mary	Bohling	Michigan Sea Grant
Leah	Boissoneau	Union of Ontario Indians Youth Council
Dave	Borgeson	Michigan DNR Fisheries
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Appendix C
Viability Indicators

Indicators identified by working groups as potentially valuable but for which current status was not rated and, for some, indicator ratings are lacking due to poorly understood relationships between the indicator and viability status.

Biodiversity Feature	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good
Open water benthic and pelagic system	Condition	Native macroinvertebrates	Mysis – Mean Density of individuals in vertical net tows at night (#/m²) at depths greater than 100m	TBD	TBD	TBD	TBD
Open water benthic and pelagic system	Condition	Native macroinvertebrates	Whitefish stomach contents	TBD	TBD	TBD	TBD
Open water benthic and pelagic system	Condition	Population size & dynamics	Coregonids: lake whitefish – numbers per/?? (Need to indicate measure -- Adults reported in Harvest?)	TBD	TBD	TBD	TBD
Open water benthic and pelagic system	Condition	Population size of offshore prey fish species	Combined Native prey fish biomass (based on multiple, selected species – to be determined by USGS)	TBD	TBD	TBD	TBD
Open water benthic and pelagic system	Condition	Population size of offshore prey fish species	Coregonids: Bloater – #/density/ bottom trawls	TBD	TBD	TBD	TBD
Open water benthic and pelagic system	Condition	Population size of offshore prey fish species	Deepwater sculpin: #/density/ bottom trawls	TBD	TBD	TBD	TBD
Open water benthic and pelagic system	Condition	Population size of offshore prey fish species	Emerald shiner: total BIOMASS? in hydro-acoustic surveys	TBD	TBD	TBD	TBD
Open water benthic and pelagic system	Condition	Population size of offshore prey fish species	Lake herring: total BIOMASS/ NUMBERS? Based on hydro-acoustic surveys	<10	10--50	51--100	>100
Open water benthic and pelagic system	Condition	Population size of offshore prey fish species	Nine-spine stickleback: total catch per 100 bottom trawls??	TBD	TBD	TBD	TBD
Open water benthic and pelagic system	Condition	Population structure & recruitment	Coregonids: Menominee – multiple year classes appear in assessment gear		Open water benthic and pelagic system	Condition	Population structure & recruitment
Open water benthic and pelagic system	Condition	Population structure & recruitment	Coregonids: lake whitefish – Growth based on asymptotic	TBD	< 700 mm	Approx. 700 mm	> 700 mm

Biodiversity Feature	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good
			length				
Open water benthic and pelagic system	Condition	Species composition / dominance	Phytoplankton species composition	TBD	TBD	TBD	TBD
Nearshore	Landscape Context	Water level fluctuations	Annual range of lake level	30-40 yr cycle shows severe trend in either water level, wavelength, or amplitude; Low level crisis = 176.02, High level crisis = 177.15	30-40 yr cycle shows significant trend in either water level, wavelength, or amplitude; Low level alert = 176.23, High level alert =176.99	30-40 yr cycle shows moderate trend in either water level, wavelength, or amplitude	30-40 yr cycle reflects consistency in water levels, wavelength and amplitude of highs and lows; Long-term average (since 1900) = 176.4
Coastal Wetlands	Condition	Community architecture	Percentage cover invasive species	>50%	>30-50%	>10-30%	0-10%
Coastal Wetlands	Condition	Presence / abundance of keystone species	Esocid index	TBD	TBD	TBD	TBD
Coastal Wetlands	Condition	Presence / abundance of keystone species	Muskrat abundance	Wetland average house density (ahd) <0.5/ha	Wetland ahd of 0.5 - 1.5/ha	Wetland ahd of 1.5/ha	Wetland ahd of >1.5/ha
Coastal Wetlands	Condition	Primary productivity	Biomass of algae	High planktonic and benthic algal biomass (PC1 >2.5)	High to moderate planktonic and benthic algal biomass (PC1 of 0 to 2.5)	Moderate to low planktonic and benthic algal biomass (PC1 of 2.5 to 0)	Low planktonic and benthic algal biomass (PC1 of -2.5 or lower)

Biodiversity Feature	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good
Coastal Wetlands	Condition	Trophic structure	Wetland Zooplankton Index (WZI)	<1.75	1.75 - 2.75	> 2.75 - 3.75	>3.75
Coastal wetlands	Landscape Context	Water level fluctuations	Annual range of lake level	30-40 yr cycle shows severe trend in either water level, wavelength, or amplitude; Low level crisis = 176.02, High level crisis = 177.15	30-40 yr cycle shows significant trend in either water level, wavelength, or amplitude; Low level alert = 176.23, High level alert =176.99	30-40 yr cycle shows moderate trend in either water level, wavelength, or amplitude	30-40 yr cycle reflects consistency in water levels, wavelength and amplitude of highs and lows; Long-term average (since 1900) = 176.4
Coastal Wetlands	Landscape Context	Water level fluctuations	Hydroperiod (period of time when wetland is covered with water)	Lake levels constant all the time	Interannual variation <1 m	Periodic lows during growing season	Reaching low of 73 m at x locations
Coastal Wetlands	Landscape Context	Water level fluctuations	Vegetative composition (area of shrub, sedge meadow, emergent, SAV)	Wetlands occupy more narrow zone, dominated by one spp or community; invasion of woody vegetation	2-3 vegetation zones are represented in a wide wetland	3-4 vegetation zones are represented in a somewhat narrower wetland	4-5 vegetation zones are represented in a wide wetland
Coastal Terrestrial	Landscape Context	Water level fluctuations	Annual range of lake level	30-40 yr cycle shows severe trend in either water level, wavelen	30-40 yr cycle shows significant trend in either water level, wavelen	30-40 yr cycle shows moderate trend in either	30-40 yr cycle reflects consistency in water levels, wavelength and

Biodiversity Feature	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good
				gth, or amplitude; Low level crisis = 176.02, High level crisis = 177.15	gth, or amplitude; Low level alert = 176.23, High level alert =176.99	water level, wavelength, or amplitude	amplitude of highs and lows; Long-term average (since 1900) = 176.4
Aerial Migrants	Size	Population size	number of fall migrants--NLH	rare/rarely used	uncommon/infrequently used	common/frequently used	abundant/always used
Aerial Migrants	Size	Population size	number of fall migrants--SLH	rare/rarely used	uncommon/infrequently used	common/frequently used	abundant/always used
Aerial Migrants	Size	Population size	number of spring migrants--NLH	rare/rarely used	uncommon/infrequently used	common/frequently used	abundant/always used
Aerial Migrants	Size	Population size	number of spring migrants--SLH	rare/rarely used	uncommon/infrequently used	common/frequently used	abundant/always used

The text below summarizes the indicators that were not incorporated into the viability assessment but are suggested for development and application to future assessments of viability. The indicators appear in the same order as in the table above.

Open Water Benthic and Pelagic System

CONDITION

Key Ecological Attribute: Native macroinvertebrates

<u>Indicator: Mysis – mean density of individuals in vertical net tows at night (#/m²) at depths greater than 100m</u>

Description: Mysis is another important native invertebrate that is less well understood than Diporeia. This indicator tracks density in deep open water areas where it plays a key role at the base of the food chain.

Indicator rating rationale: Mysis densities have only recently begun to be studied. Ongoing studies by USGS and Canadian DFO may provide information to establish ratings. Lakes Michigan and Ontario have been studied for a longer period of time and should serve as a reference for Lake Huron.

Indicator: Whitefish stomach contents

Description: Stomach contents can be used to assess the percentage of native vs. non-native mussels. Data will need to be calibrated by size or age class to reflect different feeding habits.

Indicator rating rationale: Data are being collected but were unavailable for use in this assessment.

Key Ecological Attribute: Population size and dynamics

Indicator: Coregonids: lake whitefish – numbers per/?? (Need to indicate measure -- Adults reported in Harvest?)

Description: This indicator would be a measure of abundance but is not yet fully developed. Data are being collected both on the US and Canadian sides of the lake: OMNR is using small mesh gillnet sampling and USGS is bottom trawling.

Indicator rating rationale: The ratings for this indicator are not yet developed.

Key Ecological Attribute: Population size of offshore prey fish species

Indicator: Combined native prey fish biomass (based on multiple, selected species – to be determined by USGS)

Description: This indicator will be developed by USGS based on multiple selected species and probably based on biomass data.

Indicator rating rationale: Ratings are not yet developed but are under consideration by USGS researchers.

Indicator: Coregonids: Bloater – #/density/ bottom trawls

Description: This indicator is based on data being collected by USGS and is highly variable across the lake. Experts indicate it may not be as useful as other indicators and may be dropped from this assessment in the future.

Indicator rating rationale: Indicator ratings have not been developed; USGS is collecting data and will be assessing ratings in the future.

Indicator: Deepwater sculpin: #/density/ bottom trawls

Description: USGS is collecting data on sculpin on a regular basis, but the terms of this indicator are not yet developed.

Indicator rating rationale: Ratings have yet to be developed and will be based on USGS data.

Indicator: Emerald shiner: total BIOMASS? in hydro-acoustic surveys

Description: Biomass data for the emerald shiner are being collected by USGS via hydro-acoustic surveys.

Indicator rating rationale: Ratings for this indicator have yet to be developed.

Indicator: Lake herring: total BIOMASS/ NUMBERS? Based on hydro-acoustic surveys

Description: Data on lake herring biomass and numbers are being collected via hydro-acoustic surveys and historic data can be found in GLFC Lake Huron Technical Committee reports.

Indicator rating rationale: Ratings have been developed based on long-term data but are still rough; future surveys and analyses should lead to refinement.

Indicator: Nine-spine stickleback: total catch per 100 bottom trawls??

Description: Data on the nine-spine stickleback are being collected and historic data can be found in GLFC Lake Huron Technical Committee reports.

Indicator rating rationale: Ratings for this indicator have not been developed.

Key Ecological Attribute: Population structure & recruitment

Indicator: Coregonids: menominee – multiple year classes appear in assessment gear

Description: This indicator is potentially more valuable for the nearshore system, but is maintained here for future consideration. The number of year classes is a useful measure of this prey species' abundance, given that they are infrequently caught.

Indicator rating rationale: Indicator ratings have yet to be developed.

Indicator: Coregonids: lake whitefish – growth based on asymptotic length

Description: This indicator is a measure of growth and is closely tied to food availability. It is particularly important for older year classes of lake whitefish.

Indicator rating rationale: The value of 700 mm for asymptotic length is well accepted by experts based on work by the MDNR Lake Huron Fisheries Research Station (Jim Johnson pers. comm.).

Key Ecological Attribute: Species composition / dominance

Indicator: Phytoplankton species composition

Description: This indicator has yet to be fully developed but was proposed by experts to reflect the importance of species composition in the native phytoplankton community, to provide a broader picture of overall native biodiversity in Lake Huron.

Indicator rating rationale: Ratings are not yet developed for this indicator.

Nearshore

LANDSCAPE CONTEXT

Key Ecological Attribute: Water level fluctuations

Indicator: Annual range of lake level

(see discussion for this indicator under Coastal Wetlands)

Coastal Wetlands

CONDITION

Kea: Community architecture

Indicator: Percentage cover of invasive species

Description: This indicator was suggested by the working group but requires further development prior to application.

Key Ecological Attribute: Presence/abundance of keystone species

Indicator: Esocid index

Description: This indicator was suggested by the working group but requires further development prior to application.

Indicator: Muskrat abundance

Description: This indicator was suggested by the working group but requires further development prior to application.

Key Ecological Attribute: Primary productivity

Indicator: Biomass of algae

Description: This indicator was suggested by the working group but requires further development prior to application.

Key Ecological Attribute: Trophic structure

Indicator: Wetland Zooplankton Index (WZI)

Description: This indicator was suggested by the working group but requires further development prior to application.

LANDSCAPE CONTEXT

Key Ecological Attribute: Water level fluctuations

Indicator: Annual range and timing of lake level (seasonal fluctuations)

Description: Alterations of the natural range and variability of water levels may change the location and type of the natural shoreline, expose or inundate shallow-water areas at inopportune times, alter nearshore flow and circulation patterns, and hydraulically isolate and disconnect coastal wetland complexes that cannot migrate down slope. Wetlands are adapted to varying water levels, and dampened variation will result in diminished diversity within wetlands

Indicator rating rationale: The ratings reflect a range of potential annual water level cycles ranging from an unnatural and constant regime (POOR) to a natural and expected annual water level fluctuation (GOOD). In the absence of quantitative ratings, this report has chosen qualitative ratings based on best professional judgment. The working group was unable to rate the current status of this indicator.

Indicator: Annual range of lake level

Description: Water levels in Lake Huron fluctuate in cycles of varying lenth including 160 years (long term hydrologic cycle), 33 years (medium term hydrologic cycle), 4 to 8 years (short term hydrologic cycle), and one year cycle (seasonal variations due to change in rainfall, runoff and temperature). The working group suggests that the medium-term cycle is an important indicator.

Indicator rating rationale: The working group suggested a possible set of thresholds for this indicator based on part of the mandate of the 1993 Reference Level Study. In that study, the Task Group was assigned the mission of developing a set of "crises threshold limits" (both high and low) for the Great Lakes - St. Lawrence River system; that is, thresholds (water levels) which could signify crisis conditions for which effective emergency measures should be considered and implemented. In this study "crises threshold limits" are defined as those water levels (either high or low) beyond which major damages begin to occur as a result of the magnitude of levels or flows. These thresholds, as described below, require more discussion in all cases fall within observed lake levels that have occurred within the last 150 years. The nature of the potential damage from such levels requires more discussion in the context of viability of the biodiversity features of Lake Huron.

In the determination of crises threshold levels, a number of information sources were used, including the IJC Orders of Approval, reports of damage elevations of past events, low water datum (LWD) or chart datum levels, the Basis of Comparison's (BOC) 5% and 95% exceedence probability net basin supply condition (5% reflecting wet and 95% reflecting dry conditions) levels, knowledge of the needs of the various interests groups, and overall knowledge of the Great Lakes - St. Lawrence River system. Lakes

Michigan-Huron's low water crises threshold level was selected at 175.81 metres (576.80 feet) and high crises threshold level was selected at 176.94 metres (580.50 feet) (IJC Reference Level Study, Annex 2 1993).

Indicator: Annual Hydroperiod (period of time when wetland is covered with water)

Description: Length of time of inundation relative to expected conditions.

Indicator rating rationale: Coastal wetlands have evolved to adapt to water level fluctuations within a range of variation, and current work is characterizing the area and periodicity of inundation in wetlands (Wei and Chow-Fraser 2008).

Coastal Terrestrial

LANDSCAPE CONTEXT

Key Ecological Attribute: Water level fluctuations

Indicator: Annual range of lake level

(see discussion for this indicator under Coastal Wetlands)

Aerial Migrants

SIZE

Key Ecological Attribute: Population Size

Indicators: Number of fall migrants and Number of spring migrants (for northern and southern Lake Huron)

Description: The number of migrants using a site can vary considerably from day-to-day or even year-to-year due to weather events. This indicator examines the number of fall migrants and provides an understanding of the habitat quality during the fall.

Indicator rating rationale: The qualitative criteria used are sufficient for now, but no data are available to support a current rating. As comparative data become available regarding relative use of sites this criterion can be more explicit or be more refined to reflect condition of birds or contribution of a site to fitness of birds. Current data do not allow us to be any more specific than this at this time.

Appendix D
Complete List of Strategies

Complete list of conservation strategies identified during the Lake Huron Biodiversity Conservation Strategy workshop series. These Conservation Strategies are organized under 8 categories of conservation actions[1], aimed at abating key threats to the biodiversity conservation features of Lake Huron. Conservation strategies in shaded rows are the 21 Priority Conservation Strategies detailed in Chapter 6.

Strategy		Threat(s) Abated	Scale Of Implementation
1. Land and Water Protection Strategies			
Strategy 1.1	Effectively conserve a system of public and private conservation lands for coastal terrestrial and nearshore features that are resilient to changes in land use and climate.	Climate Change; Housing and Urban Development and Shoreline Alteration	Regional/Local
Strategy 1.2	Effectively conserve critical wetlands, coastal terrestrial systems and islands predicted to remain viable under climate change and enhance viability.	Climate change	Basin-wide framework, with local implementation
Strategy 1.3	Conserve priority coastal habitats that are unprotected and vulnerable to loss and degradation.	Housing and Urban Development and Shoreline Alteration	Basin-wide
Strategy 1.4	Identify priority coastal terrestrial and nearshore habitats that are unprotected and vulnerable to loss and degradation.	Housing and Urban Development and Shoreline Alteration	Basin-wide
Strategy 1.5	Zone and protect priority/sensitive areas.	Non-point Source Pollution	Place-based
Strategy 1.6	Increase protection of existing inland wetlands.	Non-point Source Pollution	Basin-wide and place-based
2. Land and Water Management Strategies			
Strategy 2.1	Implement an integrative approach to barrier management that accounts for ecological and social values.	Dams and Other Barriers	Lake Huron Basin-wide

[1] Categories of conservation actions modified from the World Conservation Union-Conservation Measures Partnership (IUCN-CMP) classification of conservation actions (version 1.1). See: Salafsky et al. 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conservation Biology 22:897-911.

Strategy		Threat(s) Abated	Scale Of Implementation
Strategy 2.2	Implement improved septic technologies, including conversion of targeted septic systems to municipal or communal sewage systems.	Non-point Source Pollution	Lake Huron Basin-wide
Strategy 2.3	Implement targeted agricultural best management practices (BMPs) to address non-point source pollution impacts to Lake Huron biodiversity.	Non-point Source Pollution	Regional/Local
Strategy 2.4	Develop and implement an integrative, adaptive, and harmonized framework for coastal management within selected US and Canadian geographic regions.	Housing and Urban Development and Shoreline Alteration	Regional/Local
Strategy 2.5	Restore priority coastal terrestrial and nearshore features.	Housing and Urban Development and Shoreline Alteration	Regional/Local
Strategy 2.6	Develop and implement programs that identify and conserve priority nearshore and coastal terrestrial habitats.	Housing and Urban Development and Shoreline Alteration	Lake Huron Basin-wide
Strategy 2.7	Mitigate human responses to climate change in coastal areas (e.g., shoreline structures and shoreline development).	Climate change	Basin-wide framework, with local implementation
Strategy 2.8	Address non-point source pollution potentially exacerbated by climate change.	Climate change	Basin-wide framework, with local implementation
Strategy 2.9	Design precautionary fisheries policy and management strategies to account for anticipated population changes based on climate change impacts.	Climate change	Basin-wide
Strategy 2.10	Support climate change mitigation strategies implemented by other organizations and agencies.	Climate change	Federal and basin-wide
Strategy 2.11	Restore aquatic and terrestrial connectivity related to dams and barriers and shoreline development in light of climate change impacts.	Climate change	Basin-wide framework, with local implementation
Strategy 2.12	Prevent spread of invasive species predicted to spread due to climate change.	Climate change	Multiple scales –please list the scales
Strategy 2.13	Minimize impacts from new dams and barriers.	Dams and Other Barriers	Place-based
Strategy 2.14	Prevent new impassible dams and barriers.	Dams and Other Barriers	Place-based

Strategy		Threat(s) Abated	Scale Of Implementation
Strategy 2.15	Manage dams to mimic natural flow processes.	Dams and Other Barriers	Basin-wide
Strategy 2.16	Install alternative, or modify existing structures (including poorly designed or maintained culverts), to allow for ecological connectivity, restored chemical cycling, and sediment flow.	Dams and Other Barriers	Basin-wide
Strategy 2.17	Remove critical dams where appropriate.	Dams and Other Barriers	Basin-wide
Strategy 2.18	Promote and support Integrated Pest Management (IPM) for invasive species.	Non-native Invasive Species	Basin-wide
Strategy 2.19	Increase application of effective controls of invasive species.	Non-native Invasive Species	Place-based
Strategy 2.20	Implement Hazard Analysis Critical Control Points (HACCP): Increase application of effective risk management strategies for invasive species.	Non-native Invasive Species	Great Lakes wide
Strategy 2.21	Monitor white-list species and promote native species over non-native species.	Non-native Invasive Species	Great Lakes-wide
Strategy 2.22	Improve barriers at canals.	Non-native Invasive Species	Place-based
Strategy 2.23	Implement targeted best management practices, including cover crops and/or no-till or minimum-till.	Non-point Source Pollution	Broad basin-wide targeting; focused place-based targeting and implementation
Strategy 2.24	Implement targeted best management practices including conservation easements (e.g., CRP).	Non-point Source Pollution	Place-based
Strategy 2.25	Promote precision farming.	Non-point Source Pollution	Broad basin-wide targeting; focused place-based targeting and implementation
Strategy 2.26	Improve road-stream crossings to reduce sedimentation.	Non-point Source Pollution	Place-based
Strategy 2.27	Restore or create targeted inland wetlands.	Non-point Source Pollution	focused place-based targeting and implementation
Strategy 2.28	Develop, test, and implement drain/ditch naturalization and management of water levels.	Non-point Source Pollution	Broad basin-wide targeting; focused place-based targeting and implementation
Strategy 2.29	Implement Low Impact Development (LID) technologies to reduce run-off.	Non-point Source Pollution	Place-based
Strategy 2.30	Work with forest landowners in targeted areas to develop comprehensive forest management plans.	Non-point Source Pollution	Place-based

Strategy		Threat(s) Abated	Scale Of Implementation
Strategy 2.31	Educate federal, state and local provincial governments on the need for targeted best management practice implementation support.	Non-point Source Pollution	Basin-wide
Strategy 2.32	Strengthen state and provincial forest management soil and water quality standards and promote implementation.	Non-point Source Pollution	Basin-wide
Strategy 2.33	Promote the development and implementation of alternative strategies to deal with waste (e.g., biodigestion).	Non-point Source Pollution	Basin-wide and place-based
Strategy 2.34	Classify agricultural drains with regard to fishery habitat potential and work with drain commissioners to improve habitat.	Non-point Source Pollution	Basin-wide
3. Species Management Strategies			
Strategy 3.1	Restore native populations of Lake Huron's aquatic and terrestrial species.	Non-native Invasive Species	Regional/Local
4. Education and Awareness Strategies			
Strategy 4.1	Enhance knowledge, technical skills and information exchange to build capacity of local policy and land use planning authorities to include biodiversity values into their decisions.	Housing and Urban Development and Shoreline Alteration	Regional/Local
Strategy 4.2	Better educate the public on climate change issues: by creating credibility and a sense of urgency for climate change mitigation strategies being implemented across the basin, and by providing information about observed and expected climate changes affects in Lake Huron that is easily understood.		Great Lakes Basin-wide
Strategy 4.3	Increase community engagement, awareness, understanding, and commitment to coastal terrestrial and nearshore conservation.	Housing and Urban Development and Shoreline Alteration	Regional/Local
Strategy 4.4	Provide stakeholder education or outreach programming (end-use consumers and industries) to affect spread of invasive species.	Non-native Invasive Species	Great Lakes wide
Strategy 4.5	Conservation groups proactively promote best management practices.	Non-point Source Pollution	Place-based and basin-wide
Strategy 4.6	Improve quality and quantity of field services/tech support for implementation of best management practices.	Non-point Source Pollution	Broad, basin-wide implementation; place-based targeting of staff

Strategy		Threat(s) Abated	Scale Of Implementation
5. Law and Policy Strategies			
Strategy 5.1	Eliminate ballast water as a vector for invasive species introductions.	Non-native Invasive Species	Great Lakes Basin-wide
Strategy 5.2	Influence policy regulating water inflow and outflow to include ecological criteria and account for potential climate change impacts.	Climate change	Basin-wide
Strategy 5.3	Strengthen or draft trade policy/regulation for invasive species.	Non-native Invasive Species	Great Lakes wide
Strategy 5.4	Monitor the culture of non-native, potentially invasive species in aquaculture.	Non-native Invasive Species	Great Lakes wide
Strategy 5.5	Promote ban of phosphorus in lawn fertilizers.	Non-point Source Pollution	Basin-wide/community/ state/province
Strategy 5.6	Broaden/strengthen forest certification among small landowners.	Non-point Source Pollution	Basin-wide
Strategy 5.7	Promote self-policing among loggers and consultants.	Non-point Source Pollution	Basin-wide
6. Livelihood, economic and other Incentives Strategies			
Strategy 6.1	Develop economic incentives for ecosystem services programs.	Non-point Source Pollution	Lake Huron Basin-wide
Strategy 6.2	Conduct evaluation of ecological, social, economic, and ecosystem service benefits of targeted best management practices, especially with emphasis on how benefits are influenced under climate change scenarios.	Non-point Source Pollution	Basin-wide
7. External Capacity Building Strategies			
Strategy 7.1	Develop and implement a data and knowledge management system designed to guide future conservation actions and effectively track implementation efforts.	All	Great Lakes Basin-wide
Strategy 7.2	Form a SWAT Team to eradicate new invasive species before establishment/naturalization.	Non-native Invasive Species	Lake Huron Basin-wide
8. Research Strategies			
Strategy 8.1	Establish a system for monitoring biodiversity and climate change in sentinel watershed sites.	Climate Change	Great Lakes Basin-wide

Strategy		Threat(s) Abated	Scale Of Implementation
Strategy 8.2	Assess the value of ecological goods and services provided by Lake Huron, including how values are altered under climate change scenarios.	Housing and Urban Development and Shoreline Alteration; Non-point Source Pollution; Climate Change	Great Lakes Basin-wide
Strategy 8.3	Develop a Lake Huron-wide risk assessment that informs strategies for the prevention of invasive species.	Non-native Invasive Species	Lake Huron Basin-wide
Strategy 8.4	Conduct place-based research and development of control techniques non-native invasive species.	Non-native Invasive Species	Regional/Local
Strategy 8.5	Conduct a comprehensive assessment of key action areas for mitigation of agriculture, urban, and forest non-point source pollution, with special regard for areas important to biodiversity features and areas where climate change is anticipated to exacerbate current problems.	Non-point Source Pollution; Climate Change	Lake Huron Basin-wide
Strategy 8.6	Enhance research and monitoring of the nearshore and coastal terrestrial margin.	Housing and Urban Development and Shoreline Alteration	Great Lakes Basin-wide

Appendix E
Summary of Ecosystem Significance, Threats, and Capacity for the Top 100 Coastal and Island Units

The following table is a summary of ecosystem significance, threats and capacity for the top 100 coastal and island units. If a given coastal unit or island complex scored in the top quantile for a given feature, it is indicated in the table with a ❖ symbol. The coastal units and island complexes are grouped by the nine subregions.

		BIODIVERSITY FEATURES					**THREATS**	**CAPACITY**	
Name	**Lake Huron Region**	**Coastal Wetland - Ecosystem Significance**	**Coastal Terrestrial - Ecosystem Significance**	**Islands**	**Aerial Migrants - Ecosystem Significance**	**Total Score**	**Coastal Development Footprint**	**Conservation - Protected Areas**	**Conservation - Conservation Plans**
2FA-06	Bruce Peninsula	❖	❖		❖	3	1	1	0
2FA-07	Bruce Peninsula	❖	❖		❖	3	1	0	0
2FA-08	Bruce Peninsula	❖	❖		❖	3	1	0	0
2FA-12	Bruce Peninsula	❖	❖		❖	3	0	0	0
Russel Island	Bruce Peninsula			❖	❖	2	1	1	1
Cove Island	Bruce Peninsula			❖	❖	2	1	1	1
Lyal Island	Bruce Peninsula			❖	❖	2	1	0	1
2FA-04	Bruce Peninsula		❖		❖	2	1	0	1
Hay Island	Bruce Peninsula			❖	❖	2	1	0	0
Griffith Island	Bruce Peninsula			❖	❖	2	1	0	0
Indian Island	Bruce Peninsula	❖			❖	2	1	0	0
2FA-05	Bruce Peninsula		❖		❖	2	1	0	0
2FA-01	Bruce Peninsula		❖		❖	2	0	0	1
2FA-03	Bruce Peninsula		❖		❖	2	0	0	1
2FA-02	Bruce Peninsula		❖		❖	2	0	0	0
Beausoleil Island	Georgian Bay		❖	❖		2	1	1	1

Name	Lake Huron Region	BIODIVERSITY FEATURES					THREATS	CAPACITY	
		Coastal Wetland - Ecosystem Significance	Coastal Terrestrial - Ecosystem Significance	Islands	Aerial Migrants - Ecosystem Significance	Total Score	Coastal Development Footprint	Conservation - Protected Areas	Conservation - Conservation Plans
2EB-02	Georgian Bay	❖	❖			2	1	1	0
Parry Island	Georgian Bay		❖	❖		2	1	0	0
2EA-06	Georgian Bay	❖	❖			2	1	0	0
Little La Cloche Island	Manitoulin Island		❖	❖	❖	3	1	0	0
Great La Cloche Island	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-02	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-03	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-08	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-09	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-11	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-14	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-20	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-23	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-24	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-26	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-27	Manitoulin Island		❖	❖	❖	3	1	0	0
2CG-13	Manitoulin Island		❖	❖	❖	3	0	0	0
2CG-16	Manitoulin Island		❖	❖	❖	3	0	0	0
Amedroz Island	Manitoulin Island		❖		❖	2	1	0	0
Bedford Island	Manitoulin Island			❖	❖	2	1	0	0
Clapperton Island	Manitoulin Island			❖	❖	2	1	0	0
Fitzwilliam Island - East	Manitoulin Island			❖	❖	2	1	0	0
Yeo Island	Manitoulin Island			❖	❖	2	1	0	0
Northwest Burnt Island	Manitoulin Island			❖	❖	2	1	0	0
Strawberry Island	Manitoulin Island			❖	❖	2	1	0	0
Barrie Island	Manitoulin Island			❖	❖	2	1	0	0
Vidal Island	Manitoulin Island			❖	❖	2	1	0	0
GB6-63	Manitoulin Island			❖	❖	2	1	0	0
Fitzwilliam Island - West	Manitoulin Island			❖	❖	2	1	0	0
Great Duck Island	Manitoulin Island			❖	❖	2	1	0	0
2CG-04	Manitoulin Island			❖	❖	2	1	0	0
2CG-05	Manitoulin Island			❖	❖	2	1	0	0
2CG-10	Manitoulin Island			❖	❖	2	1	0	0
2CG-15	Manitoulin Island			❖	❖	2	1	0	0
2CG-22	Manitoulin Island			❖	❖	2	1	0	0
2CG-25	Manitoulin Island			❖	❖	2	1	0	0
2CG-28	Manitoulin Island			❖	❖	2	1	0	0
2CG-29	Manitoulin Island			❖	❖	2	1	0	0
2CG-30	Manitoulin Island			❖	❖	2	1	0	0
2CG-31	Manitoulin Island			❖	❖	2	1	0	0
2CG-12	Manitoulin Island		❖	❖		2	0	0	0
2CG-18	Manitoulin Island			❖	❖	2	0	0	0

Name	Lake Huron Region	BIODIVERSITY FEATURES					THREATS	CAPACITY	
		Coastal Wetland - Ecosystem Significance	Coastal Terrestrial - Ecosystem Significance	Islands	Aerial Migrants - Ecosystem Significance	Total Score	Coastal Development Footprint	Conservation - Protected Areas	Conservation - Conservation Plans
2CG-19	Manitoulin Island		❖	❖		2	0	0	0
Beckwith Island	Nottawasaga Bay		❖	❖	❖	3	1	0	1
Christian Island	Nottawasaga Bay		❖	❖	❖	3	1	0	1
Hope Island	Nottawasaga Bay			❖	❖	2	1	0	1
Sunset Point Island Complex	Nottawasaga Bay			❖	❖	2	1	0	0
2ED-05	Nottawasaga Bay	❖			❖	2	0	0	0
2ED-16	Nottawasaga Bay		❖		❖	2	0	0	0
Maisou Island	Saginaw Bay			❖	❖	2	1	1	1
Charity Island	Saginaw Bay			❖	❖	2	1	1	0
Heisterman Island	Saginaw Bay			❖	❖	2	1	1	0
Middle Grounds Island - North	Saginaw Bay			❖	❖	2	1	1	0
Middle Grounds Island - South	Saginaw Bay			❖	❖	2	1	1	0
Wild Fowl Bay Rush Cut	Saginaw Bay			❖	❖	2	1	1	0
Pitchers Reef	Saginaw Bay			❖	❖	2	1	0	1
Au Gres Island Complex	Saginaw Bay			❖	❖	2	1	0	1
Au Gres Coastal Marsh?	Saginaw Bay			❖	❖	2	1	0	1
Port Austin Reef Light Complex	Saginaw Bay			❖	❖	2	1	0	0
Burnt Cabin Point	Saginaw Bay			❖	❖	2	1	0	0
North Island	Saginaw Bay			❖	❖	2	1	0	0
Wild Fowl Bay Complex	Saginaw Bay			❖	❖	2	1	0	0
Au Gres South - Old Marina Channel Walls	Saginaw Bay			❖	❖	2	1	0	0
Au Gres River Channel Wall and Dikes	Saginaw Bay			❖	❖	2	1	0	0
Big Creek-Frontal Lake Huron	Saginaw Bay	❖			❖	2	0	0	0
2FD-01	South Lake Huron	❖	❖		❖	3	0	0	0
LH4-168	South Lake Huron			❖	❖	2	1	0	0
LH4-174	South Lake Huron			❖	❖	2	1	0	0
LH4-201	South Lake Huron			❖	❖	2	1	0	0
2FF-02	South Lake Huron		❖		❖	2	0	1	0
Kettle Point North Island	South Lake Huron	❖		❖		2	0	0	0
Drummond Island - Main	St. Marys River	❖	❖	❖	❖	4	1	0	0
Drummond Island - South Central	St. Marys River		❖	❖	❖	3	1	0	0
McKay Creek-Frontal Lake Huron	St. Marys River	❖	❖		❖	3	1	0	0
Drummond Island - Southeast	St. Marys River			❖	❖	2	1	1	0
Lime Island	St. Marys River			❖	❖	2	1	1	0
Marquette Island (Les Cheneaux Islands)	St. Marys River			❖	❖	2	1	0	1
St. Joseph Island - Southeast	St. Marys River			❖	❖	2	1	0	0
Sugar Island	St. Marys River			❖	❖	2	1	0	0
Neebish Island	St. Marys River			❖	❖	2	1	0	0
Gogomain River-Frontal Saint Marys River	St. Marys River	❖			❖	2	1	0	0
2CA-06	St. Marys River			❖	❖	2	1	0	0
2CA-08	St. Marys River			❖	❖	2	1	0	0

Name	Lake Huron Region	BIODIVERSITY FEATURES					THREATS	CAPACITY	
		Coastal Wetland - Ecosystem Significance	Coastal Terrestrial - Ecosystem Significance	Islands	Aerial Migrants - Ecosystem Significance	Total Score	Coastal Development Footprint	Conservation - Protected Areas	Conservation - Conservation Plans
2CA-09	St. Marys River			❖	❖	2	1	0	0
Drummond Island - Southwest	St. Marys River			❖	❖	2	0	0	0
Charlotte River-Frontal Saint Marys River	St. Marys River	❖			❖	2	0	0	0
Swan River-Frontal Lake Huron	West Lake Huron	❖	❖		❖	3	1	0	0
Black River-Frontal Lake Huron	West Lake Huron	❖	❖		❖	3	0	0	0
Thunder Bay Island	West Lake Huron			❖	❖	2	1	1	0
Round Island	West Lake Huron			❖	❖	2	1	1	0
Sulphur Island	West Lake Huron			❖	❖	2	1	0	1
LH6-321	West Lake Huron			❖	❖	2	1	0	0
Middle Island	West Lake Huron			❖	❖	2	1	0	0
Crooked Island	West Lake Huron			❖	❖	2	1	0	0
Sugar Island	West Lake Huron			❖	❖	2	1	0	0
Round Island Complex	West Lake Huron			❖	❖	2	1	0	0
Bois Blanc Island	West Lake Huron			❖	❖	2	1	0	0
Little Black River-Frontal Lake Huron	West Lake Huron		❖		❖	2	1	0	0