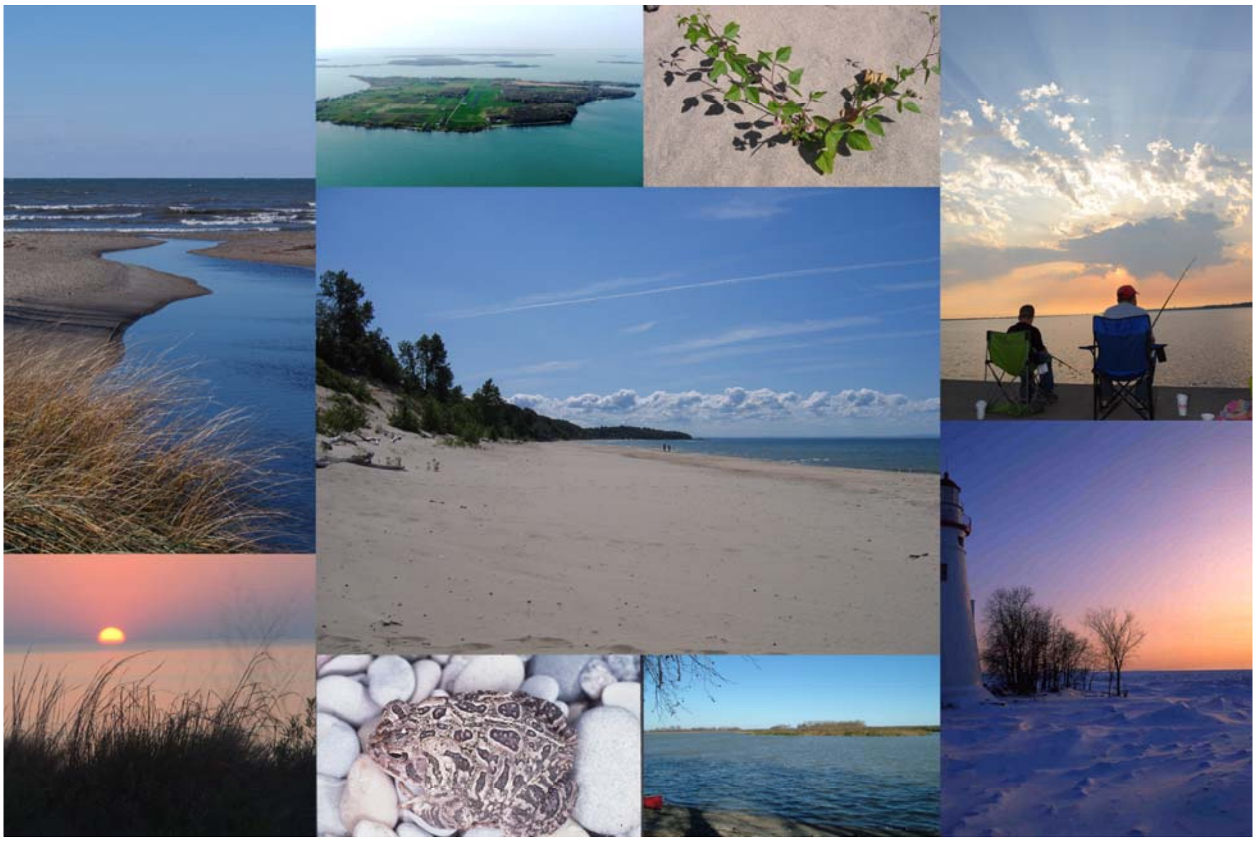
Returning to a Healthy Lake

An International Biodiversity Conservation Strategy for Lake Erie



Technical Report

The Nature Conservancy

Nature Conservancy of Canada

Michigan Natural Features Inventory

Prepared by the Lake Erie Biodiversity Conservation Strategy Core Team

Cover photo credits

From top left corner going clockwise: Lake Erie (John Whitney, NRCS District Conservationist, East Aurora, NY); North Bass Island (Williams; Ohio DNR); *Strophostyles helvola* (Mike J. McMurtry); Fairport Harbor (Randall Schieber); Marblehead (Ohio DNR); Woodtick Peninsula from Erie Marsh Preserve (Douglas Pearsall, TNC); Fowler's Toad (Mike J. McMurtry); Headlands Beach (Randall Schieber). Center photo: Beach at Marcy's Woods (Mike J. McMurtry)

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Disclaimer

This report reflects the best efforts of the Core Team and contributors to accurately represent the expertise and views expressed by project participants. The Conservation Action Planning process is iterative in nature and the Lake Erie Biodiversity Conservation Strategy should be revisited and updated periodically as conditions and available information change.

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PREFACE: 2012 GREAT LAKES WATER QUALITY AGREEMENT

The Great Lakes Water Quality Agreement (GLWQA) is a formal agreement between the governments of the United States and Canada established under the authority of the 1909 Boundary Waters Treaty. It was first signed in 1972 under the administrations of President Nixon and Prime Minister Trudeau. The agreement established basinwide water quality objectives and binational commitment on the design, implementation and monitoring of associated programs. The GLWQA was revised in 1978 and 1987.

The 1978 GLWQA included a new purpose statement to reflect a broadened goal, "to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem." The ecosystem approach concept introduced in the Revised 1978 Agreement recognized the interconnectedness of all components of the environment and the need for an integrated perspective in addressing human health and environmental quality issues. The 1978 Agreement also called for the virtual elimination of persistent toxic substances in the Great Lakes ecosystem by adopting a philosophy of "zero discharge" of inputs and established a list of toxic chemicals for priority action.

The GLWQA was amended again by protocol in 1987. New concepts of ecosystem-based management were incorporated including the development and adoption of ecosystem objectives for the lakes. The Protocol also included two new annexes focusing on provisions to develop and implement Remedial Action Plans (RAPs) to restore impaired water uses for significantly degrades areas around the Great Lakes (known as Areas of Concern) and Lakewide Management Plans (LaMPs) to address whole lake contamination by persistent toxic substances. Several other new annexes were also introduced, further broadening the scope of the Agreement: non-point contaminant sources; contaminated sediment; airborne toxic substances; contaminated groundwater; and associated research and development.

In June of 2010, the governments of Canada and the United States initiated renegotiation of the Agreement to meet current challenges. On September 7, 2012, Canada and the United States officially amended the Agreement. The 2012 GLWQA facilitates United States and Canadian action on threats to Great Lakes water quality and includes measures to prevent ecological harm. New provisions address the nearshore environment, aquatic invasive species, habitat degradation, and the effects of climate change. It also supports continued work on existing threats to people’s health and the environment in the Great Lakes basin such as harmful algae, toxic chemicals, and discharges from vessels.

The Lake Erie Biodiversity Conservation Strategy (LEBCS)[1] was initiated to provide a more in-depth assessment of the lake’s biodiversity status and challenges, as well as develop a comprehensive set of strategies to maintain and increase the viability of Lake Erie’s biodiversity and abate the threats to biodiversity. The Strategy aims to facilitate coordination of actions among diverse and widespread partners, providing a common vision for conservation of Lake Erie, and help to put local actions and priorities into a basin-wide context. The results of this Strategy support several of the new and updated

[1] The LEBCS was funded through the USEPA’s Great Lakes Restoration Initiative, with additional funding provided by Environment Canada.

Annexes of the 2012 GLWQA. This includes establishing baseline and assessment information that will inform future monitoring and the setting of ecosystem objectives, identifying areas of high ecological value, providing tools to assess the impacts of climate change, and the development of strategies that will support the Lakewide Action and Management Plan for Lake Erie.

EXECUTIVE SUMMARY

Lake Erie is unique among the Great Lakes. Its shallow waters and southern location result in the highest primary production, biological diversity and fish production of all the Great Lakes. This highly valuable resource is also situated in the most altered basin, and has suffered from invasive species, increases in nutrient concentrations, pollution and habitat destruction. These anthropogenic changes have caused wildlife and plant populations to decline and in some locations disappear, changing Lake Erie's natural biological diversity and diminishing many of its ecological services. Through the efforts of many agencies, organizations, and individuals working over decades, Lake Erie has shown the ability to recover, and we expect that future, focused efforts will lead to further restoration of the functions and ecological richness of the lake, and the quality of life for people in the basin.

The Lake Erie Biodiversity Conservation Strategy (LEBCS) is a binational initiative designed to support the efforts of the Lake Erie LaMP by identifying specific strategies and actions to protect and conserve the native biodiversity of Lake Erie. It is the product of a two-year planning process involving over 190 from 87 agencies and organizations around the basin[2]. The goals of this planning process included:

- Assemble available biodiversity information for Lake Erie;
- Define a binational vision of biodiversity conservation for Lake Erie;
- Develop shared strategies for protecting and restoring critical biodiversity areas;
- Describe the ways in which conservation strategies can benefit people by protecting and restoring important ecosystem services; and
- Promote coordination of biodiversity conservation in the Lake Erie basin.

By applying a biodiversity focus to synthesize and prioritize existing related efforts, the LEBCS reaffirms and advances many existing complementary plans and initiatives. This project has increased awareness and collaboration among organizations and communities active in biodiversity conservation with the Lake Erie watershed, and provides a lakewide context for local conservation actions.

Designing a biodiversity strategy: Approach, scope and stratification

The Nature Conservancy's Conservation Action Planning (CAP) process – a proven adaptive management approach for planning, implementation, and measuring success for conservation projects – guided the development of the strategy (TNC 2007). This effort was managed by The Nature Conservancy, Michigan Natural Features Inventory and Nature Conservancy Canada, working closely with the Great Lakes National Program Office of the USEPA—funders of the project through the Great Lakes Restoration Initiative. A Steering Committee of 60 representatives from Federal, State, Provincial, and local agencies and organizations advised the Core Team. Involvement of these key individuals, several of whom are

[2] The scope of this project included the waters of Lake Erie, St. Clair River, Lake St. Clair, Detroit River and Niagara River, and the tributaries of these watersheds to the extent that they affect the biodiversity of the lake.

part of the Lakewide Management Plan (LaMP), LaMP Forum and Great Lakes Fishery Commission, and other experts and stakeholders throughout the basin was critical to the long-term success of this effort.

The scope of Lake Erie Biodiversity Conservation Strategy includes the lake itself, the Connecting Channels, including Lake St. Clair, St. Clair River, Detroit River and upper Niagara River, the immediate coastal area (roughly 2 km inland from the shoreline), and the watersheds of the tributaries in the basin, to the extent that they affect the biodiversity of the lake.

Assessing information and planning at broad scales, such as an entire Great Lakes basin, can present challenges for developing and tracking a set of successful strategies. Lake Erie has considerable regional variation in shoreline and nearshore ecology, economics, and dominant land use, with the most striking variation found between the Western and Eastern Basins. To address the differences within the Lake and along the coastal zone, we divided the lake into four generally recognized basins for reporting units: The reporting units are: Eastern Basin, Central Basin, Western Basin and Huron-Erie Corridor. We further divided these reporting units into offshore and coastal-nearshore units to facilitate assessments of viability (health) and threats to biodiversity and inform development of strategies.

Assessing Lake Erie's biodiversity

Eight focal targets were identified that define the biodiversity of Lake Erie:

1. **Open Water Benthic and Pelagic Ecosystem** (offshore waters deeper than 15 m)
2. **Nearshore Zone** (waters less than 15 m in depth, including the coastal margin)
3. **Native Migratory Fish** (Lake Erie fish with populations that require tributaries for a portion of their life cycle, including lake sturgeon, walleye, suckers and sauger)
4. **Lake Erie Connecting Channels** (Huron – Erie Corridor and Upper Niagara River)
5. **Coastal Wetlands** (wetlands with historic and current hydrologic connectivity to, and directly influenced by, Lake Erie)
6. **Islands** (including both naturally formed and artificial islands)
7. **Coastal Terrestrial Systems** (upland systems within ~2 km of the shoreline)
8. **Aerial Migrants** (migrating birds, insects, and bats dependent on the Lake Erie shoreline)

Engaging numerous experts and employing recognized Key Ecological Attributes (KEAs) and indicators of health, the current viability status of each of the eight targets was identified by assessment unit, reporting unit and lake wide. These assessments provide a snapshot of the status of biodiversity in Lake Erie and their desired state. Lakewide viability is presented in Table a, which also shows viability by each reporting units and by target. The long-term goals for each target are summarized in Table b. *Fair* is the predominant rating, except for Aerial Migrants where viability is *Good* in the western half of the lake. Islands have *Good* viability in the Central Basin. While this summary gives us an overall picture of Lake Erie, we also recognize that important differences exist at finer scales and provide a more detailed assessment in maps of each target in Chapter 4, and tables for each attribute assessed in Appendix E. In considering the work needed to be done to rehabilitate these targets to reach the goals presented in

Table b, it will be important to consult the finer-scale assessment, as well as focusing on those attributes most impaired.

Table a: Lakewide viability assessment summary

Target	Huron-Erie Corridor	Western Basin	Central Basin	Eastern Basin	Lakewide
Nearshore Zone	Fair	Fair	Fair	Fair	**Fair**
Aerial Migrants	Good	Good	Fair	Fair	**Good**
Coastal Terrestrial Systems	Fair	Fair	Fair	Fair	**Fair**
Coastal Wetlands	Fair	Fair	Good	Fair	**Fair**
Connecting Channels	Fair			Fair	**Fair**
Islands	Fair	Fair	Good	Fair	**Fair**
Native Migratory Fish	Fair	Fair	Fair	Fair	**Fair**
Open Water Benthic and Pelagic Ecosystem			Fair	Fair	**Fair**
Overall Biodiversity Health	**Fair**	**Fair**	**Fair**	**Fair**	**Fair**

Table a: Summary Goals for 2030 to assure long-term viability

Targets and Goals

Open Water Benthic and Pelagic Ecosystem

By 2030, to assure that the Open Water Benthic and Pelagic zone of Lake Erie is characterized by a more stable food web that supports a diverse fishery and is resilient to invasive species:

- Native fish will comprise 50% of the prey biomass;
- Lake trout will maintain self-sustaining populations in each major area of the offshore;
- Self-sustaining populations of native predators (such as yellow perch, walleye, lake whitefish and lake trout) maintain relatively stable populations consistent with Fish Community Objectives.

Nearshore Zone

By 2030, to assure adequate water quality for sustaining native plants, fish, and invertebrates:

- Based on multi-year averages, reduce the load of dissolved phosphorus by 50% by 2030 in at least the priority watersheds. HAB toxin measures will be reduced to the point that no HAB advisories at public beaches will be recorded and issued. The native fish community will have abundant populations of smallmouth bass, walleye, yellow perch, northern pike, muskellunge, rock bass, emerald shiners, white sucker and cyprinids.

Targets and Goals

Native Migratory Fish

By 2030, to provide adequate access to spawning habitat:

- At least 50% of the total length of each type of stream is connected to the lake;
- Each river-spawning Lake Erie fish species is represented by at least two viable populations in each applicable region (i.e. assessment unit) of the lake.
- Tributary connectivity is maximized for Lake Erie migratory fish, while increased risk of aquatic invasive species spread and proliferation is minimized.

Coastal Wetlands

By 2030, so that Coastal Wetlands provide adequate ecological functions and habitat for native plants and animals:

- The average wetland macrophyte index for Coastal Wetlands around the lake will reflect good condition;
- Coastal Wetland area around the lake will have increased by 10% compared to the 2011 wetland area.

Connecting Channels

By 2030, so that Lake Erie Connecting Channels continue to improve as critical habitat for the full diversity of native species:

- Shoreline hardening is below 50% along both shores;
- Coastal Wetlands in the Detroit River comprise at least 25% of historic area;
- At least one viable refuge for native mussels persists in each connecting channel;
- Spawning of river-spawning migratory fish continues to show an improving trend.

Islands

By 2030, to ensure that Islands remain as intact and sustainable ecological systems:

- A minimum of 60% of Lake Erie islands are owned and managed for conservation;
- A minimum of 80% of Lake Erie islands are in natural land cover;
- The abundance and richness of colonial nesting waterbirds is maintained within 1990-2010 range of variation;
- All islands are protected by quarantine from known vectors of invasive species;
- Maintain island habitat in an undeveloped condition to support colonial nesting waterbirds, including cormorants, on the islands that have been historically used by nesting colonial nesting waterbirds.

Coastal Terrestrial Systems

By 2030, to assure that Coastal Terrestrial System is of high quality and of sufficient extent to provide habitat for native plant and animal species:

- At least 40% of the Coastal Terrestrial System will be in natural land cover;
- Viable populations of priority nested targets are adequately represented across the lake (adequate representation will be determined at a later date;
- At least 5% of the Coastal Terrestrial System will be in good to excellent condition;
- The average artificial shoreline hardening index will be below 20%;
- All high priority biodiversity areas in the Coastal Terrestrial System are minimally affected by shoreline alterations

Aerial Migrants

By 2030, so that Lake Erie remains a globally significant stopover area for migrating birds:

- At least 30% of the 2 km coastal area comprises high quality stopover habitat for migrating landbirds;
- At least 10% of the coastal area comprises high quality stopover habitat for migrating shorebirds;
- At least 50% of the 2 km coastal area including coastal wetlands comprises high quality stopover habitat for migrating waterfowl;
- At least 80% of the 2 km coastal area that is high quality stopover habitat for all bird groups is in conservation ownership or management.

Identifying critical threats

To assess threats to biodiversity, the Core Team compiled a list of threats from previous lake-wide and regional CAPs, and the Steering Committee provided additional suggestions to complete the initial list. We then developed online surveys, one for each of the five reporting units, inviting experts to rate the threat to each target in that reporting unit, and document their level of confidence with each rating. Threats were ranked according to scope (size of area), severity of impact (intensity of the impact), and irreversibility (length of recovery time). We received 40 responses and using a weighted-averaging approach that considered the respondent's expertise level, we calculated overall threat-to-target ranks and also calculated ratings for threats across all targets and overall threat ratings for each target.

Threats ranked *Very High* or *High* by reporting unit:

- **Huron – Erie Corridor**: aquatic invasive species; shoreline alterations; pollution (agricultural); terrestrial invasive species; housing & urban development; climate change; point source pollution (industrial);
- **Western Basin**: shoreline alterations; non-point source pollution (agricultural); aquatic invasive species; terrestrial invasive species; housing and urban development; climate change;
- **Central Basin**: non-point source pollution (agricultural); aquatic invasive species; terrestrial invasive species; climate change;
- **Eastern Basin**: shoreline alterations; non-point and point-source pollution (urban and household); non-point source pollution (agricultural); aquatic invasive species; terrestrial invasive species; housing and urban development; climate change; contaminated sediments.

Lakewide, the most critical threats to biodiversity are: aquatic invasive species; climate change; terrestrial invasive species; non-point source pollution (agriculture and forestry); housing and urban development, shoreline alterations; contaminated sediments, point source pollution (industrial, urban and household), dams and other barriers.

To address the most critical threats to biodiversity and restore badly degraded conservation targets, the Core Team hosted a strategy development workshop in Detroit in December, 2011. In the workshop, participants brainstormed and identified priority strategies and, for the top one to three strategies, developed objectives and measures for five topics; the sixth topic, dams and barriers, was addressed through subsequent webinars and conference calls:

1. Agricultural non-point source pollutants
2. Invasive species (aquatic and terrestrial)
3. Housing and urban development and shoreline alterations
4. Urban non-point and point source pollutants
5. Dams and barriers

While recognized as a critical threat, climate change was not addressed in isolation at the workshop. Rather, we worked with participants in the groups above to identify key climate-related vulnerabilities of targets, and ways in which factors like increases in temperature or increases in peak storm intensities should influence the framing or relative priority of strategies.

Developing conservation strategies

Developing conservation strategies requires a thorough understanding of how critical threats and their causal factors influence the health of biodiversity features. We created conceptual models to illustrate visually how social, political, economic, and environmental elements act together to perpetuate direct and indirect threats to biodiversity targets of Lake Erie. Based on these models, workshop participants identified specific strategies to abate these threats, identified highest priority strategies, and developed a detailed set of outcomes for at least one. The final set of eight featured biodiversity conservation strategies for Lake Erie are presented in Table c in the third column.

Climate change was a key consideration in several of the above strategies. For example, the likely increases in the intensity of storm events is an important consideration in planning for non-point source pollution management , and improving connectivity helps fish and other aquatic species respond to increasing temperatures.

Priority areas

To complement the lake-wide strategies and better direct conservation action at the local scale, we conducted an analysis of ecological significance analysis to rank smaller coastal units and islands in Lake Erie. We were able to rank priority areas for four of the seven biodiversity targets. For Coastal Terrestrial and Coastal Wetland targets, we conducted a novel analysis of biodiversity significance and condition. For Aerial Migrants and Islands, we used two recently completed research studies that identified priority areas. Priority areas are not relevant to the Open Water Benthic and Pelagic zone, and while relevant to Native Migratory Fish and the Nearshore Zone, we lack sufficient data to do this type of analysis.

The Rondeau Point coastal watershed unit (CWU), located on the Canadian side of the Central Basin received the highest Coastal Terrestrial biodiversity score. Other units that fell into the very high category included: Lower Portage River and Cedar Creek, both located in the Ohio portion of the Western Basin; Canard River on the Ontario side of the Detroit River; Lake Erie North on the Ontario side of the Eastern Basin; and South Otter Creek located in the Ontario portion of the Central Basin just west of Long Point. The top seven coastal watershed units (CWU) with the highest Coastal Terrestrial condition scores are all located in Canada. The Tyrconnell Creek unit located in the Central Basin received the highest score.

Only two of the units with high terrestrial biodiversity scores, Rondeau Point and South Otter Creek CWUs, both located on the Canadian side of the Central Basin, also had relatively high terrestrial condition scores. The only unit with high biodiversity values and low condition scores is the Canard River unit. This unit is located on the Ontario side of the Detroit River and appears to have high potential for ecological restoration.

Table c. Summary of featured strategies in the Lake Erie Biodiversity Conservation Strategy

Strategy	Key factors in situation analysis	Strategies selected for focus in workshop
1. Reducing the Impact of Agricultural Non-Point Source Pollutants;	• Erosion • BMP funding issues • BMP implementation • Cropping trends/prices • Drainage • Altered hydrology • Freshwater pollutants • Nutrient management/Fertilizer application • Climate change – more intense storms, drought stress	a. Target and intensify adoption of nutrient management BMPs to reduce Soluble Reactive Phosphorus loadings to Lake Erie • Identify where to target implementation of best management practices (priority watersheds) • Increase adoption of 4 R's (right place, right time, right rate, and right type) to guide fertilizer application (likely by fertilizer retailers); provide knowledge to support 4 R's; certification program b. Promote in-field management of water and management of surface and subsurface drainage and management of surface drainage channels to moderate discharge extremes and limit nutrient losses (to be developed)
2. Preventing and Reducing the Impact of Invasive Species (aquatic and terrestrial);	• Risk/vulnerability because of degradation • Trade/consumer demand • Vectors – forage/seed, retail practices, transportation, human movement of forest products, bait • Climate change/range expansion, • Lack of funding, awareness, knowledge, capacity • Inadequate coordination • Ecosystem impacts • Regulatory structure • Need for surveillance • Lack of control methods	a. Develop a common framework for aquatic invasive species control and management for Lake Erie • Establish a basin-wide working group • With increased political support, establish new policy and regulations for control and prevention • Form basin-wide response team • Demonstrate effectiveness of ecological restoration in controlling and managing AIS b. Assemble key regional partners to create a coordinated action plan for Common Reed and other priority terrestrial invasive species • Apply control • Coordinate regulation to improve efficiency and rapidity of control • Improve coordination for early detection and rapid response to Common Reed

Strategy	Key factors in situation analysis	Strategies selected for focus in workshop
3. Coastal Conservation: Preventing and reducing the impacts of Incompatible Development and Shoreline Alterations	• Awareness/understanding • Political: lack of will and funding/incentives to protect shoreline, emphasis on growth/tax base • Sociocultural and socioeconomic: demand, property values, aesthetic/recreational values, commercial development pressure, ability to participate in decision making, lack of clarity for ownership responsibility • Knowledge: cumulative effects, long term costs, research, monitoring, accessibility of information • Planning: scale of decision making, lack of comprehensive plans, priorities, professional experience	a. Build a business case for coastal conservation • Specific conservation goals and associated costs, key stakeholders, and right scale of analysis are determined • Economic and social benefits of conservation alternatives are evaluated • Stakeholders ,affected sectors, and decision makers all support conservation alternatives • Funding and incentives for coastal protection established • With needed funding, integrated coastal zone adaptive management plans created and implemented; impacting local decision making b. Develop a comprehensive education and outreach program for healthy shorelines • Shoreline processes and land owner behavior understood • Comprehensive toolbox created that provides decision support for prioritization, contractor training, demonstration sites, and economic assessments • With foundation of support for healthy shorelines, updated regulations developed and implemented, and applied where needed
4. Reducing the Impacts of Urban Non-Point and Point Source Pollutants	• Imperviousness/storm water • Lack of enforcement • Emerging contaminants - untreated • Legacy pollutants/marina contaminants • Municipal land use regs • Dredging/disposal • Resuspension • Increase in coal burning • Climate change – more intense storms • Urban NPS • PS – sources – industrial, municipal, household	a. Improve municipal storm water management throughout the basin to mitigate impacts • On developed lands through enforcement and retrofit • Through prevention on newly developed lands (through regulations/zoning that requires BMPs and protection of sensitive features) • Assumes individual municipalities can benefit from pooling resources to meet storm water permit requirements by collaborating with other watershed partners and stakeholders

Strategy	Key factors in situation analysis	Strategies selected for focus in workshop
5. Improving Habitat Connectivity by Reducing the Impact of Dams and Other Barriers	• Pressure to keep barriers include financial cost of removal, aesthetic values, risk of further invasive species spread • Pressures to remove or improve barriers: risk of failing infrastructure and associated costs, management objectives to improve fisheries and/or ecological conditions, and aesthetics.	a. Increase connectivity to Lake Erie, focusing on first barriers • Initially focuses on development of evaluation criteria and decision tool to assess ecological benefits and risks, economic costs and benefits, cultural and social values associated with a barrier, and opportunity • The decision tool would be used to influence four pathways to barrier removal – use by international management groups, incorporation into watershed management plans, and directing of funding resources to barriers, as well as individual municipal decisions on barriers.

The highest scoring units for Coastal Wetland biodiversity are Cedar Creek and Pickerel Creek CWUs both located in the Ohio portion of the Western Basin, and the Swan Creek CWU located on the northwest portion of Lake St. Clair in Michigan. Units with the highest Coastal Wetland condition scores are Mill Creek/Black River and Swan Creek both located in Michigan in the northern portion of the Huron-Erie Corridor.

The Swan Creek CWU in Anchor Bay was the only unit to score relatively high for both biodiversity value and condition. However, this unit has relatively high building and road densities as well as one of the highest percentages of artificial shorelines in Lake Erie. The Cedar Creek and Pickerel Creek CWUs in Ohio were the only two units in Lake Erie with a high biodiversity score but very low condition score.

The Aerial Migrants target is based on a study developed by Ewert et al. (2012 draft) to model and assess migratory bird stopover sites in the Great Lakes Basin. The preliminary results of the modeling study highlight the Western Basin, Huron-Erie Corridor (strong emphasis on the Canadian side), and the Ontario portion of the Eastern Basin as containing significant habitat for both shorebirds and waterfowl during spring migration.

For the Islands target, we used the results from a recent study (Henson et. al. 2010) that assessed the biodiversity value of all Great Lakes islands. Key islands for biodiversity conservation in Lake Erie include: Pelee Island, Pointe Aux Pins, Long Point, and Turkey Point all located in Ontario, and Kellys Island in Ohio. Key islands in the Huron to Erie Corridor include Harsens Island in Michigan, and Walpole Island, Squirrel Island, St. Anne Island Complex, and Johnston Channel Island Complex all located in Ontario.

Ecosystem services

While the LEBCS strategies are intended to address threats to and restore biodiversity, experts around the lake clearly agree that the strategies are very likely to have positive effects on human well-being. We conducted two surveys to: 1) identify the 10 most important ecosystem services provided by Lake Erie and its coastal area, and 2) estimate the potential effect (in qualitative terms) of the proposed conservation strategies on those important ecosystem services.

Participants from all five Lake Erie basin states and the province of Ontario, representing public agencies at all levels of government, as well as private organizations and others, completed the survey. Recreation and wildlife habitat were identified as the two most important ecosystem services, and, not surprisingly, supplying fresh water, purifying water, and the water cycle were all among the top ten. Other benefits in the top ten included primary productivity, aesthetics, nutrient cycling, “sense of place”, and climate regulation.

Among the recommended strategies, reducing impacts from agricultural and urban non-point and point source pollution were estimated to have the greatest positive effect on these ecosystem services, followed by coastal conservation. Services that were identified as most likely to be improved included wildlife and fish habitat, recreation, and aesthetics. There were no strategies that were thought to have negative effects on ecosystem services, and no ecosystem services that were predicted to be degraded by the recommended strategies.

Implementation recommendations

The LEBCS presents key components of a common vision for the conservation of Lake Erie biodiversity. The strategies (with associated goals, objectives and measures) are designed to augment efforts to fulfill obligations of the Great Lakes Water Quality Agreement (GLWQA) as updated in 1987 and 2012, the Great Lakes Restoration Action Plan, and a host of other local and regional priorities (see Appendix K). We conclude this report with several general recommendations to facilitate implementation of the LEBCS. These recommendations include:

1. The Lake Erie LaMP adopts the LEBCS and affirms a common vision and priorities.
2. Lakewide organizations review and restructure to meet implementation needs.
3. Expand stakeholder engagement to include corporate and industrial sectors, as well as local-regional government.
4. Leader and stakeholders adopt a common vision and agenda and then develop an Implementation Plan.
5. LEBCS is viewed as a living document and is regularly updated using adaptive management as a standard component of the review, analysis, and business planning processes.
6. Align funding streams to achieve LaMP priority outcomes.

1. INTRODUCTION

1.1. Lake Erie: Lake of the Panther

Box 1: Lake Erie Basin Facts[3]

Surface Area: **25,700 km^2**
Basin Area: **103,000 km^2**
Surface: Basin Ratio: **1:4**
Water Volume: **484 cubic km**
Average Depth: **19 m**
Maximum Depth: **64 m**
Replacement Time: **2.6 years**
Shoreline Length: **4,001 km (including islands)**
Area Coastal Wetlands: **2,790+ km^2**
Length of Sand Beaches: **403 km**
Number of People in the Basin: **12.4 M**
Number of Cities >100,000 people: **4**
Largest City: **Cleveland OH (394,000)**
Provides Drinking Water to: **11 M**
Commercial Fisheries Catch: **10,000 MT**
Value of Commercial Fishery: **$194 M**

Lake Erie is the most southern and shallow lake in the Great Lakes system. Situated between Lake Huron and Lake Ontario, the drainage basin includes Ontario, Michigan, Ohio, Pennsylvania, New York and a small portion of Indiana in the western headwaters of the Maumee River. Lake Erie is the 15th largest lake in world by volume and can be divided into three major basins. The western basin is defined by shallow waters, with maximum depth of only 18.9 m, and an archipelago of over 30 islands that reaches from the Marblehead Peninsula in Ohio to Pelee Island in Ontario. The large central basin extends from the eastern edge of the western basin to the Pennsylvania Ridge, a low, wide submerged ridge located between the Long Point and Erie sand spits with 25 m depth. The eastern basin is the deepest, with a maximum depth of 64 m (Bolsenga and Herdendorf 1993).

The shallow waters, post-glacial history and relatively southern location of Lake Erie set it apart from the other Great Lakes. The shallow waters promote well-developed submergent vegetation in the littoral zones, which provide excellent nursery and forage habitat for many fish species. Coastal wetland complexes provide important habitat for many species and filter the water draining into the lake from the surrounding watershed. The shallow, southern waters Lake Erie have the highest primary production, biological diversity and fish production of all the Great Lakes.

Lake Erie was the first of the Great Lakes to appear on the landscape as the glaciers retreated, and as new habitat arose, plants and animals from the east, south and west expanded their ranges to colonize the basin (U.S. EPA 2006). Freshwater fish moved in from refuges in both the Mississippi and Atlantic drainage basins, driving the high diversity of aquatic species we see today (Mandrak and Crossman 1992). Some of these species moved into the Lake Erie basin and became uniquely adapted and diverged from their relatives. The Lake Erie Watersnake (*Nerodia sipedon insularum*) has one of the smallest ranges of any vertebrate subspecies in the world. Found only in a small portion of Lake Erie, it is uniquely adapted to the geology of the Great Lakes (Seymour and King 2003). A wide array of Coregonid fish evolved specifically to the Great Lakes. Lake Erie had both the shortjaw cisco (*Coregonus zenithicus*)

[3] http://www.great-lakes.net/lakes/ref/eriefact.html;
http://www.canadiangeographic.ca/magazine/so03/indepth/justthefacts.asp;
http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_096931.pdf
http://binational.net/solec/sogl2009/SOGL_2009_nearshore_en.pdf

and the lake cisco (*Coregonu artedi*) also known as lake herring (Bronte et al. 2010). These obligate planktivores provided the prey base for larger fish and supported one of the most productive fisheries in Lake Erie, until they were functionally extirpated in the 1920's by overfishing, predation by invasive species and loss of spawning habitat due to siltation (Coldwater Task Group 2011).

The coastal systems of the Lake Erie basin are dominated by bluffs, sand beaches and wetlands. Over 335 km of bluffs occur along all regions of Lake Erie. Many of these bluffs have narrow beaches at their toe and are an important source of sediment for beaches. Lake Erie and Lake St. Clair has 403 km of sand beaches, with the most extensive beaches at Long Point, the southeastern coast and in the western basin. Several of these beaches have associated dune systems. One of the most unique features of Lake Erie is its four sand spits: Point Pelee, Rondeau, and Long Point in Ontario, and Presque Isle in Pennsylvania. Over 2,792,680 km^2 of coastal wetlands have been documented from Lake Erie (SOLEC 1996, 2009). While wetlands occur along most of the coast, most of the coastal wetland area in concentrated in large wetland systems including St. Clair Delta, Mouillee Marsh, Ottawa National Wildlife Refuge, Point Pelee, Rondeau and Long Point.

The basin of Lake Erie includes three major connecting channels: the Huron – Erie Corridor (i.e. St. Clair River and the Detroit River) flowing into Lake Erie and the Niagara River conveying water from Lake Erie to Lake Ontario. These connecting channels have been heavily modified and much of the shoreline, particularly along the St. Clair and Detroit Rivers, is artificial. Lake Erie receives 80% of its water from the Detroit River. The remaining contributing water is from rivers and streams entering the lake (12%) and direct precipitation (8%). The relatively small volume of Lake Erie results in a water residency time of only 2.6 years, the shortest of all the Great Lakes.

The name of Lake Erie was taken from the First Nations that lived along the south shore during first contact with Europeans in early 1600s. Erie is a short form of the Iroquoian word *Erielhonan* meaning "long tail" and refers to the panther (or Eastern Cougar) that the Erie people were identified with. Early French explorers referred to this tribe as Nation du Chat, or Cat Nation. Part of the Iroquois Nation, they lived in what is now western New York, northwestern Pennsylvania, and northern Ohio. They were decimated by warfare with the neighboring Iroquois in the 18th century and ultimately absorbed by other Iroquoian tribes, particularly the Seneca, and gradually lost their independent identity (Grady 2007).

The diverse eastern forests that once supported the Cat Nation and the Eastern Cougar around Lake Erie have been dramatically altered in the last 400 years - the lake and its basin are the most impacted in the entire Great Lakes system. Most of the basin is now characterized by intensive agriculture, and includes the cities of Detroit, Windsor, Toledo, Cleveland and Buffalo. The current population in the basin is approximately 12.4 million.

Exploitation of Lake Erie from the turn of the century through the 1970s left it seriously degraded, and permanently altered the physical and chemical regime of the lake. Anthropogenic phosphorus inputs caused algal blooms that blanketed the water's surface and depleted oxygen from the lake as they decayed. This led to degraded water quality and significant fish die offs. Lake Erie became the archetype of Great Lakes issues in the 1970s, and was referred to as the “dead lake” due to industrial pollution, including the 1969 fire on the Cayuga River, and massive algal blooms from high phosphorus inputs. Environmental protection efforts in the 1970’s including the establishment of the Great Lakes Water Quality Agreement (1972) have reduced some of these impacts. Major efforts to reduce phosphorus inputs, especially from wastewater treatment plants and through conservation tillage to reduce agricultural erosion, led to greatly improved water quality (e.g., Ludsin et al. 2001), and reversed the highly eutrophic conditions and eliminated the algal blooms in Lake Erie by the 1980s (Ohio EPA 2010), although the some of the phosphorus loading and related problems have returned over the next two decades.

Despite these significant stressors, the Lake Erie ecosystem has shown resilience. Lake Erie still has one of the largest freshwater fisheries in the world (U.S. EPA 2011a); almost 10,000 metric tons of fish were caught commercially from Lake Erie in 2011 (Government of Ontario 2012, ODNR 2012). Tourism and recreation generate more than $10 billion in visitor spending within Ohio’s coastal counties (Ohio Sea Grant 2012). The lake also provides water for irrigation of agricultural lands, a route for transportation and shipment of goods, and moderation of the regional climate.

However, while Erie’s tributaries no longer catch on fire, fewer fish die-offs occur and some species have made a comeback, such as the Lake Erie Watersnake (Department of the Interior 2011) - threats from invasive species, non-point source pollution and a changing climate may continue to reduce the integrity of the lake. Much more work is needed to reverse the damage done to Lake Erie and enhance the quality of life for people that live in the basin.

1.2. Strategy scope

The health and long-term sustainability of biodiversity in Lake Erie depends on how we manage resources within the lake and basin. The scope the Lake Erie Biodiversity Conservation Strategy comprises those ecological systems and species within the lake itself, the connecting channels, the immediate coastal area (roughly 2 km inland from the shoreline) and the watersheds of the tributaries to the extent that they affect the biodiversity of the lake. This includes the geographic scope of the Lake Erie watershed as well as the open waters of the lake, including the Huron – Erie Corridor and the upper Niagara River above Niagara Falls (Figure 1).

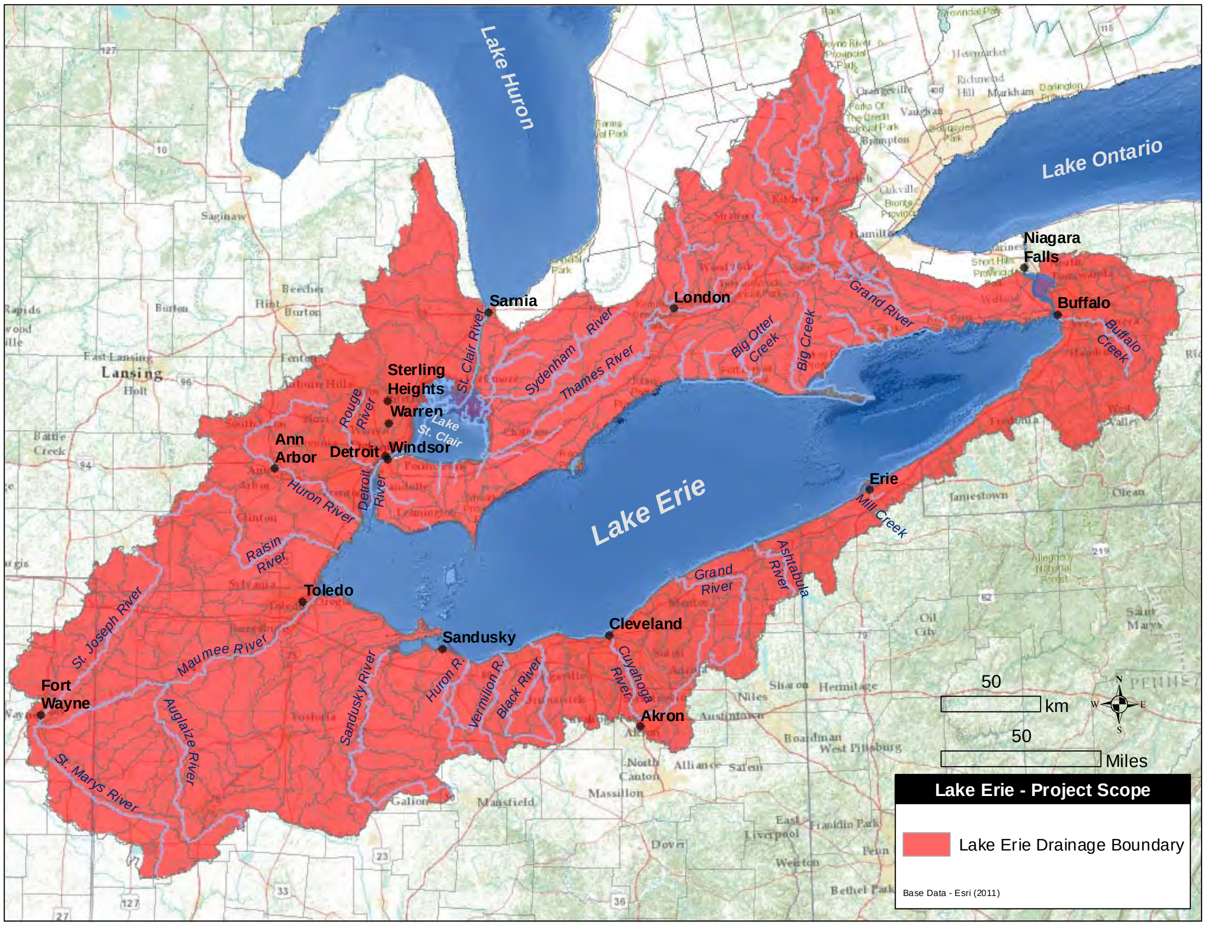

Figure 1: Geographical scope of Lake Erie Biodiversity Conservation Strategy.

1.3. Vision statement

"We envision a healthy Lake Erie that sustains the full array of natural ecosystems and the services[4] they provide. A resilient Lake Erie is sustained by collaborative, ecosystem-based management, now and into the future."

This statement reflects the key role of people in achieving the vision, and the dependence of people on the lake. This vision is further sharpened by these characteristics of a healthy Lake Erie ecosystem:

- Key ecosystem processes (e.g. lake level fluctuations, sediment transport, nutrient cycling) that are functioning within a range that is informed by natural ranges of variability, and likely climate-related shifts;

[4] Ecosystem services are the benefits people obtain, directly or indirectly, from ecosystems (MEA 2003)

- It's resilience and resistance to ongoing and future challenges;
- Adequate representation of viable occurrences of all natural communities and native species distributed throughout the basin;
- A broad recognition that the long-term well-being of human communities throughout the basin is directly linked to the health of Lake Erie's biodiversity;
- A variety of land and water based planning and management efforts that routinely incorporate biodiversity related information;
- A majority of educational systems and outdoor recreational activities for which biodiversity conservation is a core component.

1.4. Project coordination

To ensure cooperation and coordination across geopolitical boundaries and agencies involved in the LEBCS, this project was guided by a Steering Committee and managed by a Core Team. The Core Team developed and facilitated the process, and produced this final report. A Steering Committee consulted on the process, partner involvement, and content. It included 60 representatives from 36 agencies and organizations associated with the LaMP and LaMP Public Forum, as well as other stakeholders, experts, and partners. Appendix A lists the participants and agencies from the Core Team and Steering Committee.

1.5. Stakeholder and partner engagement

The Core Team provided a variety of opportunities for organizations and individuals to contribute to the LEBCS including: regular conference calls, webinars, e-mail communications, surveys, quarterly project updates, project websites, a strategy development workshop in December 2011 and attendance at meetings of the Lake Erie LaMP Public Forum and other related groups. This report is the product of a two-year planning process involving over 190 from 87 agencies and organizations around the basin who are concerned about and responsible for safeguarding the health and sustainability of Lake Erie's biodiversity and people (see Appendix B for a list of contributors).

2. AN OVERVIEW OF THE CONSERVATION ACTION PLANNING PROCESS[5]

The Nature Conservancy's Conservation Action Planning (CAP) process was used to develop the LEBCS. The CAP process is a proven technique for planning, implementing, and measuring success for conservation projects. Based on an "adaptive" approach to conservation management, the CAP process helps practitioners to focus their conservation strategies on clearly defined elements of biodiversity or conservation targets and fully articulate threats to these targets and to measure their success in a manner that will enable them to adapt and learn over time (Figure 2, TNC 2007).

Figure 2: The Conservation Action Planning Process

The main purpose of CAP is to help conservation practitioners to:

1) Identify and assess the health or viability of **biodiversity conservation targets**
2) Identify and rank **threats** to biodiversity conservation targets
3) Develop **strategies** to abate the most critical threats and enhance the health of the biodiversity conservation targets
4) Identify **measures** for tracking project success

[5] A detailed description of the CAP process can be found in the Conservation Action Planning Handbook (TNC 2007).

The Conservation Action Planning Process involves not only planning, but also implementation and adaptation. The last two steps are beyond the scope of this project, however it is worth noting that by working closely with the Lake Erie LaMP and other lake-wide and local managers, conservation practitioners, and stakeholders in other sectors in the development of this biodiversity conservation strategy, we are hopeful that the strategies can be easily integrated into ongoing and nascent projects.

While there is still much to learn on how to efficiently and effectively incorporate climate change into all aspects of the CAP process, "climate-smart" thinking was integrated into this strategy. We drew from our experiences re-evaluating CAPs for Lake Huron and Lake Ontario (as documented in Poiani et al. 2011) as we engaged in the CAP process for Lake Erie.

In this section we provide a brief overview of the two first steps of the Conservation Action Planning process in order to offer the reader with the basic elements of this framework. Appendix C includes definitions for concepts used in the CAP process. The detailed methodology used by this project is provided in each chapter and their corresponding appendixes.

2.1. Defining the project

The first stage of the process is defining the project (Figure 2; TNC 2007). Through this stage, project participants are identified including the core team, advisors or Steering Committee members, and stakeholders. In this stage the project scope is defined both conceptually and spatially. This includes the delineation of the area that encompasses the biodiversity of interest and from which threats to biodiversity could originate. Project participants and scope for this project are presented in Chapter 1. This first stage also includes the identification of biodiversity conservation targets for their ability to represent the full suite of biodiversity within the project area, including its species, natural communities, and ecological systems.

2.2. Developing strategies and measures

Developing strategies and measures consists of five main steps: 1) assessing viability of biodiversity conservation targets, 2) identifying critical threats, 3) completing a situation analysis, 4) developing conservation strategies, and 5) establishing measures.

2.2.1. Assessing viability of biodiversity conservation targets

Assessing viability entails evaluating the current "health" status and desired future status of each biodiversity conservation target. The viability assessment relies on established principles of ecology and conservation science. It uses the best available information on the biodiversity conservation target's biology and ecology in an explicit, objective, consistent, and credible manner. However viability assessment does not require "perfect" information. Instead it provides a way to portray, using the best information available, what healthy biodiversity conservation targets will look like. For many biodiversity conservation targets, consideration of responses to climate change plays an important role in defining desired future status.

The viability assessment is done through the identification of **key ecological attributes** (KEAs) and **indicators** for each biodiversity conservation target. A key ecological attribute is an aspect of a target's biology or ecology that if present, defines a healthy target and if missing or altered, would lead to the outright loss or extreme degradation of that target over time. Types of KEAs include size (or abundance), condition (measure of the biological composition, structure and biotic interactions) and landscape context (assessment of environment and ecological processes that maintain the biodiversity feature). Indicators are specific measures to keep track of the status of a key ecological attribute. In order to determine the relative condition of a given indicator for a given target a **viability rating** is established (Box 2). Finally, once the attributes and indicators for each biodiversity conservation target have been established, the next task is to assess the **current status** and set the **desired status** of the indicators assigning one of the ranking classes in Box 2.

Box 2. Viability ratings criteria 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.

Throughout this report the ratings are identified by the colors in this box.

While the current viability rating for each indicator is established based on the best available information, the CAP process uses an algorithm and a set of rules for aggregating those values for each KEA, for the whole target and for the overall project (Figure 3, see Box 3 for the rules used in this project).

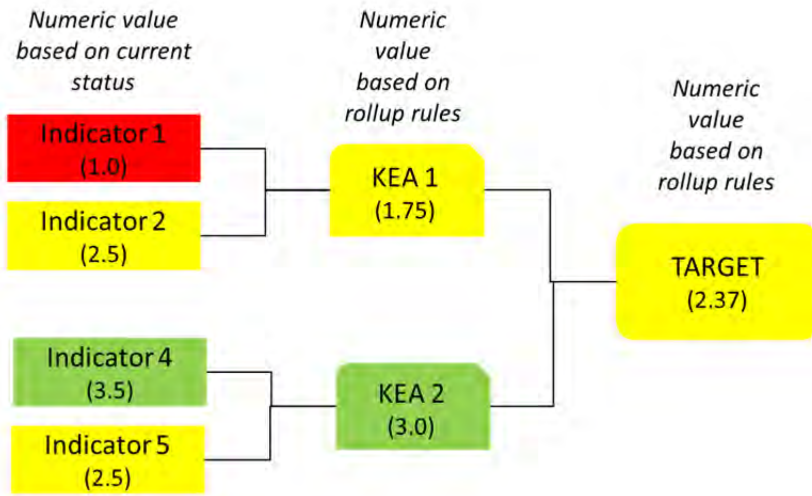

Figure 3: Example of the aggregation process used in the viability assessment (see Box 3 for aggregation rules).

Box 3. Aggregation rules for viability assessment (adapted from TNC 2003).

Each of the viability ranks has a numerical score assigned to it:

- **Very Good = 4.0**
- **Good = 3.5**
- **Fair = 2.5**
- **Poor = 1.0**

This scale is a crude approximation of the underlying continuous viability scale. The non-linear numeric relationship among the viability classes reflects the diminishing return of moving up one class as one moves up the scale. For example, the viability score increases by 1.5 in moving from 'Poor' to 'Fair,' but only increases by 0.5 in moving from 'Good' to 'Very Good.'

The rank for each KEA is derived from the average of these numeric values from the indicators, using the following ranges:

- **Very Good = 3.75 – 4.0**
- **Good = 3.0 – 3.745**
- **Fair = 1.75 – 2.995**
- **Poor = 1.0 – 1.75**

To assess the viability at the Assessment Unit and Reporting Unit levels, the indicators are first averaged within each KEA Type (landscape context, condition, and size).

2.2.2. Identifying critical threats

This step involves identifying the various factors that directly and negatively affect biodiversity conservation targets and then ranking them in order to focus conservation actions where they are most needed. This is done through the identification of stresses (degraded key ecological attributes) and sources of stress or direct threats (proximate activities or processes that have caused, are causing or

Box 4: Direct threats rating criteria used in the CAP process (TNC 2007)

Severity - The level of damage to the biodiversity conservation target that can reasonably be expected within 10 years under current circumstances (i.e., given the continuation of the existing situation).

- **Very High:** The threat is likely to destroy or eliminate the conservation target over some portion of the target's occurrence at the site.
- **High:** The threat is likely to seriously degrade the conservation target over some portion of the target's occurrence at the site.
- **Medium:** The threat is likely to moderately degrade the conservation target over some portion of the target's occurrence at the site.
- **Low:** The threat is likely to only slightly impair the conservation target over some portion of the target's occurrence at the site.

Scope - Most commonly defined spatially as the geographic scope of impact on the conservation target at the site that can reasonably be expected within 10 years under current circumstances (i.e., given the continuation of the existing situation).

- **Very High:** The threat is likely to be widespread or pervasive in its scope and affect the conservation target throughout the target's occurrences at the site.
- **High:** The threat is likely to be widespread in its scope and affect the conservation target at many of its locations at the site.
- **Medium:** The threat is likely to be localized in its scope and affect the conservation target at some of the target's locations at the site.
- **Low:** The threat is likely to be very localized in its scope and affect the conservation target at a limited portion of the target's location at the site.

Irreversibility - The degree to which the effects of a source of stress can be restored.

- **Very High:** The source produces a stress that is not reversible (e.g., wetlands converted to a shopping center).
- **High:** The source produces a stress that is reversible, but not practically affordable (e.g., wetland converted to agriculture).
- **Medium:** The source produces a stress that is reversible with a reasonable commitment of resources (e.g., ditching and draining of wetland).
- **Low:** The source produces a stress that is easily reversible at relatively low cost (e.g., off-road vehicles trespassing in wetland).

may cause the stresses) for each biodiversity target. Once direct threats are identified they are rated in terms of their scope, severity and irreversibility (Box 4). Using a rule-based system these ratings are combined to calculate the overall target-threat rating. The direct threats that are highest ranked are considered the critical threats.

2.2.3. Completing situation analysis

The situation analysis describes the relationships between biodiversity conservation targets, direct threats, indirect threats, opportunities, and associated stakeholders. This description is normally a diagrammatic illustration of these relationships (called a “conceptual model”- Figure 4). Completing a situation analysis is a process that helps creating a common understanding of the project's context, including the biological environment and the social, cultural, economic, political, and institutional systems that affect the biodiversity conservation targets. A good situation analysis clearly expresses the context in which the project will take place and illustrates the cause-and-effect relationships that exists within the project area. In other words, the analysis helps articulate the core assumptions inherent in the project, and to communicate the intentions and expected impacts of the project actions to other people outside of the project

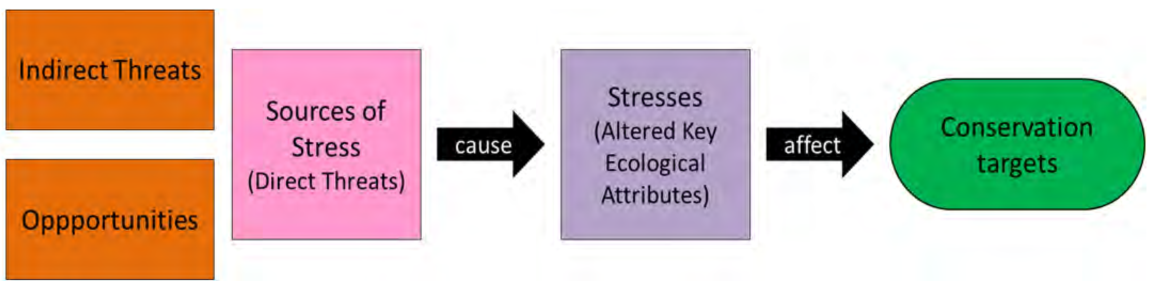

Figure 4: Elements of a conceptual model or situation analysis

2.2.4. Developing conservation strategies

A conservation strategy is a broad course of action intended to achieve a specific objective or outcome that abates a critical threat, enhances the viability of a biodiversity conservation target, or secures project resources and support. The first step of setting conservation strategies is to define objectives: specific statements detailing the desired accomplishments or outcomes of a particular set of activities within the project. The second step is, based on the situation analysis, to delineate strategic actions, which are broad or general courses of action undertaken by the project team to reach one or more of the stated objectives.

Strategies are linked to chains of factors showing the sequence of contributing factors affecting direct threats and ultimately targets. This done using a diagram, called results chain, that map out a series of causal statements that link factors in an "if...then" fashion. For example, if a threat is reduced, then a biodiversity target is enhanced. Results chains are composed of a strategy, desired outcomes including intermediate results and threat reduction results, and the ultimate impact that these results will have on the biodiversity target (Figure 5).

Finally, a set of strategic actions are selected for implementation based on their specific benefits, feasibility and costs.

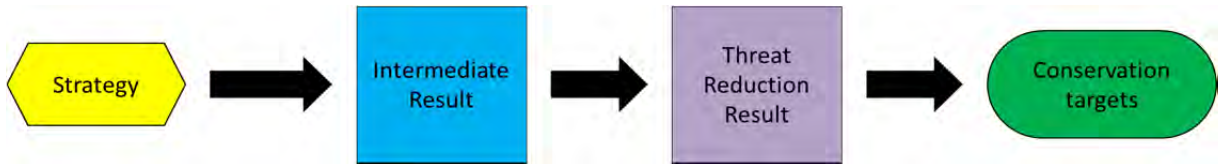

Figure 5: Elements of a results chain

2.2.5. Establishing measures

This is the final step of Developing Strategies and Measures**.** Establishing measures and creating a monitoring plan are critical to determining success of the conservation strategies. Measuring both the effectiveness of strategies and status of the biodiversity features is needed for effective adaptive management. Measures of both kinds are established in this process; the viability assessment produced measures against which biodiversity outcomes can be assessed, and indicators of effectiveness were developed for most strategies.

2.2.6. Miradi

Miradi is a project management software designed specifically as a tool to implement the Conservation Action Planning process. The software was used to manage the project, to assess the viability of conservations targets, assess and rank threats, and to develop situation analysis and result chains.

3. ADDRESSING REGIONAL HETEROGENEITY: SPATIAL STRATIFICATION

Assessing information and planning at broad scales, such as a Great Lakes basin, can present challenges for developing a set of strategies and tracking progress. Lake Erie has considerable regional variation in ecology, economics and land use, and this variation has implications for the status of biodiversity, the threats that impact biodiversity, and the effectiveness of conservation strategies.

In order to address this variability, provide greater resolution to the assessments of viability and threats to biodiversity, and to facilitate implementation of place-based actions, we have stratified Lake Erie into geographic units at two nested levels (see Appendix D for details on the methodology used to define these spatial units).

Reporting units: generally reflect accepted sub-basins within Lake Erie and are largely consistent with the Aquatic Lake Units identified in the Great Lakes Regional Aquatic Gap Analysis (McKenna and Castiglione 2010). Circulation patterns and lake bathymetry were used to delineate the boundaries of these four units. The reporting units are: Eastern Basin, Central Basin, Western Basin and Huron - Erie Corridor (Figure 6, see Appendix G for a description of each Reporting Unit).

Assessment units: the reporting units were further sub-divided into assessment units that reflect ecological patterns and processes primarily associated with two sets of targets, the coastal and nearshore areas and offshore areas. Patterns and processes that inform the delineation of these units include depth, current, substrate, temperature, large tributary (≥5th order) influences, and species distribution patterns. We established these assessment units based on familiar frameworks, including the SOLEC Biodiversity Investment Areas (BIAs) (Rodriguez and Reid 2001). Within the coastal/nearshore assessment units, we used shoreline features and mapped element occurrences (obtained from state and provincial Conservation Data Centres) to refine the boundaries between units. These units are illustrated on Figure 6.

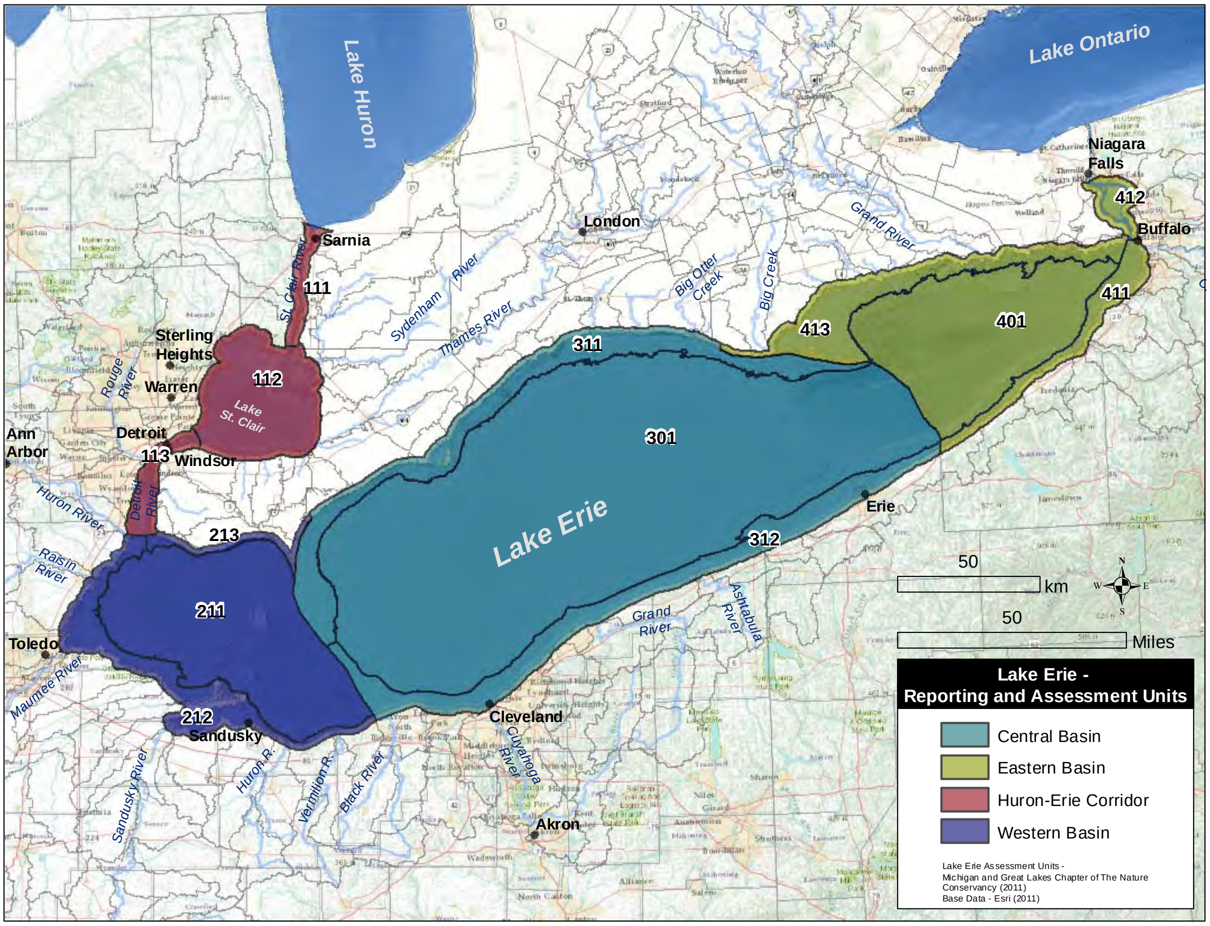

Figure 6: Lake Erie stratification units

4. BIODIVERSITY CONSERVATION TARGETS AND VIABILITY ASSESSMENT

In this chapter, we first describe each of the biodiversity conservation targets for Lake Erie, and provide a general characterization of the current viability for each target. After describing the targets and their viability we portray the viability of Lake Erie's biodiversity when all targets are considered together.

Appendix E details the viability analysis for each target including key ecological attributes (KEAs) and indicators, along with their current status and measures for each assessment unit. The rationale behind the use of each indicator along with the methods used for their analysis is included in Appendix F. Finally, details of the viability at the Reporting Unit level can be found in Appendix G.

4.1. Identifying biodiversity targets and assessing their viability:

Biodiversity conservation targets were selected based on targets selected by other Great Lakes conservation strategies (Lake Ontario Biodiversity Strategy Working Group 2009, Franks-Taylor et al. 2010), other assessments of Lake Erie and complemented with the input from the project core team, Steering Committee, and other partners (see Box 5 for a brief definition of each conservation target).

Box 5: Summary of Biodiversity Conservation Targets

1. **Open Water Benthic and Pelagic Ecosystem:** offshore waters deeper than 15 m.
2. **Nearshore Zone:** waters <15 m in depth, including the coastal margin.
3. **Native Migratory Fish:** fishes that migrate to complete part of their life cycle (e.g. lake sturgeon, walleye, suckers).
4. **Lake Erie Connecting Channels:** Huron – Erie Corridor and Upper Niagara River.
5. **Coastal Wetlands:** wetlands with historic and current hydrologic connectivity to, and directly influenced by Lake Erie.
6. **Islands:** including both naturally formed and artificial islands.
7. **Coastal Terrestrial Systems:** upland systems within ~2 km of the shoreline.
8. **Aerial Migrants:** all types of migrating birds, insects, and bats dependent on Lake Erie.

In order to assess viability, the Core Team collected initial key ecological attributes (KEAs) and indicators for Lake Erie from previous Great Lakes strategies (Lake Ontario Biodiversity Strategy Working Group 2009, Franks Taylor et al. 2010), as well as the State of the Lakes Ecosystem Conference (SOLEC) reports

(SOLEC 2005, 2007, 2009), and a literature review[6]. In order to account for the unique attributes of Lake Erie, KEAs and indicators developed for other lakes were adjusted based on information gained through the literature review and expert consultation. Generally, KEAs and indicators apply to all reporting and assessment units, however there are cases in which an indicator only applied to certain geographical area of the Lake, and thus was only used for some reporting and assessment units. KEAs and indicators were assessed at the finest scale allowing consideration of spatial variation in target viability across the Lake. KEAs and indicators can also apply to multiple conservation targets (e.g. water level fluctuations) affects the Nearshore Zone, Coastal Wetlands, Coastal Terrestrial Systems and Island targets, and indicators for this KEA appear in the viability assessment for each one.

For each indicator, the Core Team and selected experts developed initial ratings for thresholds between the Conservation Action Planning (CAP) rating categories (i.e. *Poor*, *Fair*, *Good*, or *Very Good*, see definitions in Box 2) based on the best available information and expert opinion. Indicator ratings are usually quantitative, but can be qualitative when relationships between an indicator and the viability of a biodiversity conservation target are poorly understood or information is lacking. In those cases where there was not enough information to provide ratings the indicators were considered placeholders (see details in Appendix E).

Analyses to determine the current status for many indicators were conducted using a geographical information system (GIS). The values of these indicators were mapped so experts could visualize the current values in addition to the tabulated figures (see Appendix F for details on the methods used to assess each indicator).

A broader panel of external experts was engaged via webinar or phone interview to help assign current and desired status ratings and to provide advice on indicators and thresholds. Prior to the webinars, experts were provided with draft tables of KEAs and indicators, maps of analyzed data, and descriptions of the CAP process, the stratification approach, and the viability assessment process. Webinars were recorded and a member of the Core Team took notes of the discussion. After the webinars, the Core Team followed up on specific issues of concern and re-engaged with individual experts as needed.

Though this process some important indicators were identified that lack information either to provide a threat ranking or a current status value. In those cases even if they are not used to assess the target viability the Core Team decided to include them on the viability tables (Appendix E and F) as placeholders indicating the need of further research in that specific indicator.

[6] The specific references used can be found within each target description as well as in the description of indicators in Appendix F.

Box 6. A note about desired status and goals for biodiversity conservation targets

Restoration of the Offshore Zone, Nearshore Zone, Coastal Wetland and Coastal Terrestrial Systems of Lake Erie is a primary goal of many agencies and organizations and restoration goals are often based on reference conditions that occurred in the past or in a 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 lakes and their resources, there is no place or past time that serves as a practical reference, or "end point" for restoration. Recognizing these constraints, the Core Team and experts used the most current information and their own best judgment to select and assess the KEAs and indicators presented here. The "desired future status", typically given by the rating for 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 historical reference point but may be considered, collectively, as a set of reasonable goals for restoration of biodiversity in Lake Erie. The goals that are presented for each target below are expressed in terms of indicators that most succinctly represent, in the opinion of the Core Team, a future desired status for each target.

4.2. Open Water Benthic and Pelagic Ecosystem

The Open Water Benthic and Pelagic biodiversity conservation target (or Offshore Zone) is defined in Lake Erie as the open water ecosystem beyond the 15-meter bathymetric contour from the mainland or islands, including reefs and shoals. This offshore system is found in the Central and Eastern Basins of Lake Erie (Figure 7).

Nested targets: benthic invertebrates, forage fishes (benthic and pelagic), fish and bird piscivores (benthic, pelagic, avian), shoals and reefs, phytoplankton and zooplankton.

The offshore is a highly dynamic system where natural and anthropogenic factors interact to influence the makeup of offshore communities. While depth does shape the processes and biologic composition of the offshore, the boundary between nearshore and offshore habitat is fuzzy and many species can be found in both habitats and migratory fish move through both.

The ecology of the Offshore Zone of Lake Erie varies with depth and trophic state. In the Central Basin, where the deepest point is 24 m and waters are generally meso-trophic, the Offshore Zone historically supported a fish community dominated by predatory percids, including blue pike (*Sander vitreus glaucus*), sauger (*Sander canadensis)*, walleye (*Sander vitreus*) and yellow perch (*Perca flavescens*) (Ryan et al. 2003). The deeper Offshore Zone of the Eastern Basin is oligotrophic and colder and historically supported a fish community distinct from the rest of Lake Erie. For example, two large predators, lake trout (*Salvelinus namaycush*) and burbot (*Lota lota*) dominated the offshore waters, fed by abundant lake cisco (*Coregonus artedi*) (Markham et al. 2008).

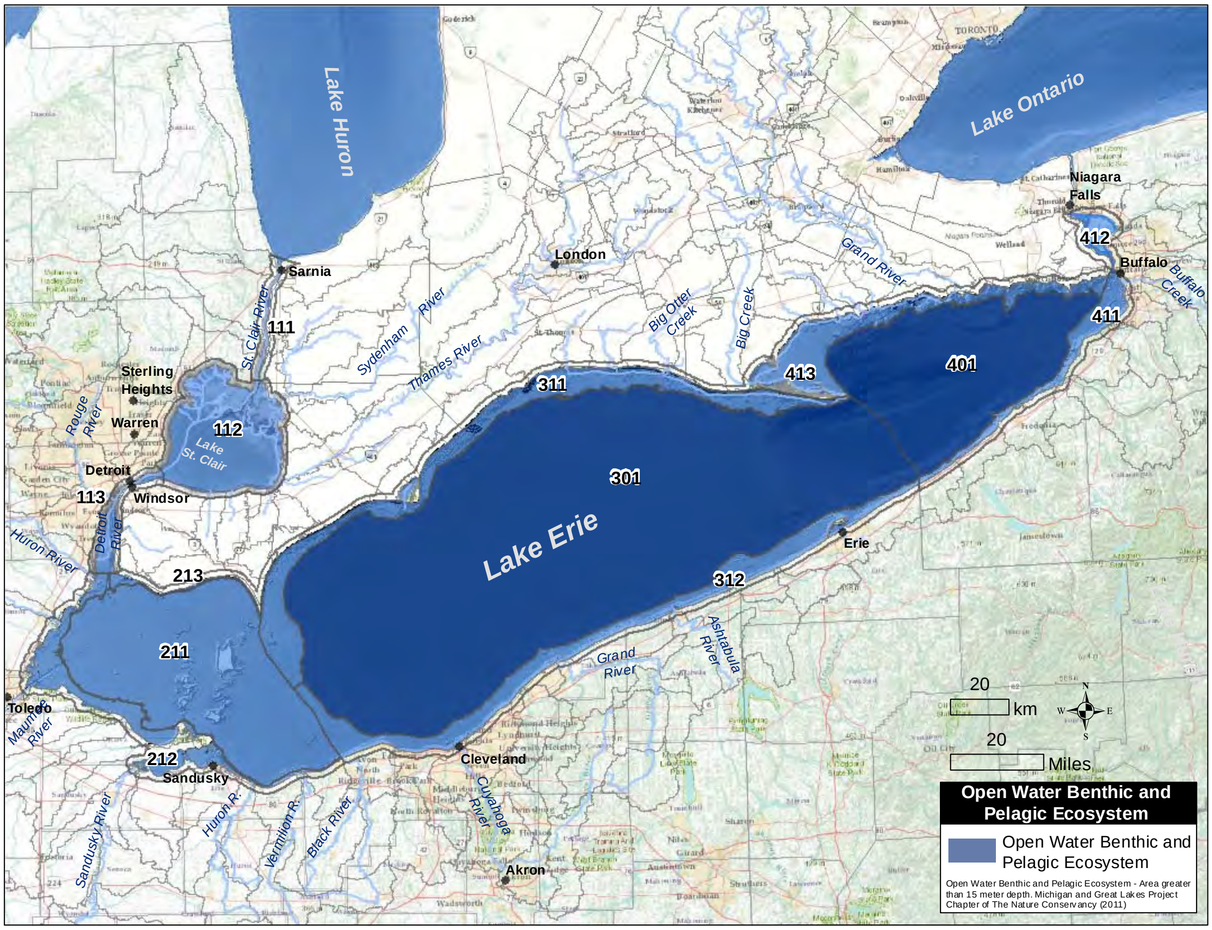

Figure 7: The Open Water Benthic and Pelagic Ecosystem or Offshore Zone of Lake Erie

Economically, Lake Erie's offshore once supported commercial harvests for multiple species. Proliferation of invasive species combined with historic eutrophication and overfishing has caused steep declines in top predator fish and the extirpation of blue pike and sauger (Ryan et al. 2003) While lake whitefish *(Coregonus clupeaformis)* are still commercially harvested in Canadian waters, lake trout are only present due to stocking efforts and valued primarily when taken as trophy-sized fish by sport fishers (Markham et al. 2008). Prey fish biomass is dominated by introduced species, especially rainbow smelt (*Osmerus mordax*), which fill the niche left empty by the decline of cisco (Coldwater Task Group 2011, Ryan et al. 2003). Lake trout restoration is a goal of the Lake Erie Committee of the Great Lakes Fishery Commission (Ryan et al. 2003) and could play an important ecological role as they feed on a range of prey, which brings stability to the fish community (Bronte et al. 2008). Walleye provide a similar stabilizing role (Ryan et al. 2003).

At lower trophic levels, high abundances of invasive dreissenid mussels, known more familiarly as zebra (*Dreissena polymorpha*) and quagga (*Dreissena rostriformis bugensis*) mussels have altered physical habitats and nutrient regimes and appear to be associated with declines in key food sources including the invertebrate *Diporeia* (Barbiero et al. 2010). While current levels of total phosphorus are within the desired range for the Eastern Basin, record algal blooms in 2011 reached into the Central Basin (NASA 2011) suggesting that excessive phosphorus usually associated with the nearshore is impacting the Offshore Zone as well.

To add complexity to an already multifacited ecosystem, the dynamics of open water species and systems (e.g. nutrient and sediment transport, food webs) within the central and Eastern Basins of Lake Erie are likely to be affected by several climate change-related drivers (discussed in more detail in Appendix H). In particular, while the species using open water, and especially benthic habitats are well buffered from increases in air temperature, strong increases in spring surface water temperatures are likely to lead to earlier initiation and longer duration of stratification (Trumpickas et al. 2009). Though changes in this key process are recognized as having the potential for widespread impacts, specific implications for fish and other nested targets are poorly understood. Possibly, changes in the timing of stratification could have ripple effects through the food web; for example if phytoplankton population dynamics respond more rapidly to surface water warming than other taxonomic groups, and mismatches occur in the timing of predator-prey interactions. Due to a lack of information and high uncertainty, this aspect of potential climate change impacts on the aquatic food web was not explicitly considered in the threat ranking or goals, but we recommend efforts to update strategies, and measure progress, should consider how these system-wide changes might influence strategy effectiveness.

Key documents that guide management efforts in the offshore zone of Lake Erie include the Great Lakes Fishery Commission's (GLFC) A Strategic Plan for the Rehabilitation of Lake Trout in Lake Erie, 2008-2020 (Markham et al. 2008), the Lake Erie Fish Community Objectives (Ryan et al. 2003), as well as the annual reports of the GLFC's Coldwater Task Group (see for example, Coldwater Task Group 2011).

Open Water Benthic and Pelagic Ecosystem Goal

By 2030, as evidence that the Open Water Benthic and Pelagic Zone of Lake Erie embodies a more stable food web that supports a diverse fishery and is resilient to invasive species:

- Native fish will comprise 50% of the prey biomass;
- Populations of native predators (such as walleye, perch, lake whitefish and burbot) will be stable;
- Lake trout will maintain self-sustaining populations in the Eastern Basin

Goals were informed by the Lake Erie Fish Community Objectives (Ryan et al. 2003), which calls for a balanced, predominantly cool-water fish community in the Central Basin, and cold-water fish community in the offshore of the Eastern Basin, with self-sustaining species. However, while these objectives recognize the importance of naturalized introduced species, for the purpose of this biodiversity assessment, we stressed in our target goals the increasing predominance of native fish.

4.2.1. Viability of the Open Water Benthic and Pelagic Ecosystem

For this assessment, the overall viability of the offshore was rated *Fair* (Figure8, see Appendix E for details). This rating reflects that although the lake is able to support sufficient prey biomass in the middle trophic levels and water quality parameters are good or nearly good, Lake Erie's top predators are declining (e.g., yellow perch, walleye, burbot, and lake whitefish) or showing no sign of recovery despite stocking efforts (lake trout). Efforts are underway to address the barriers to lake trout restoration (Markham et al. 2008) and to date no natural reproduction of lake trout has been documented. In addition, cisco have been caught that are genetically consistent with those historically found in Lake Erie, and efforts continue to do the genetic risk assessment to devise a restoration plan (Coldwater Task Group 2011).

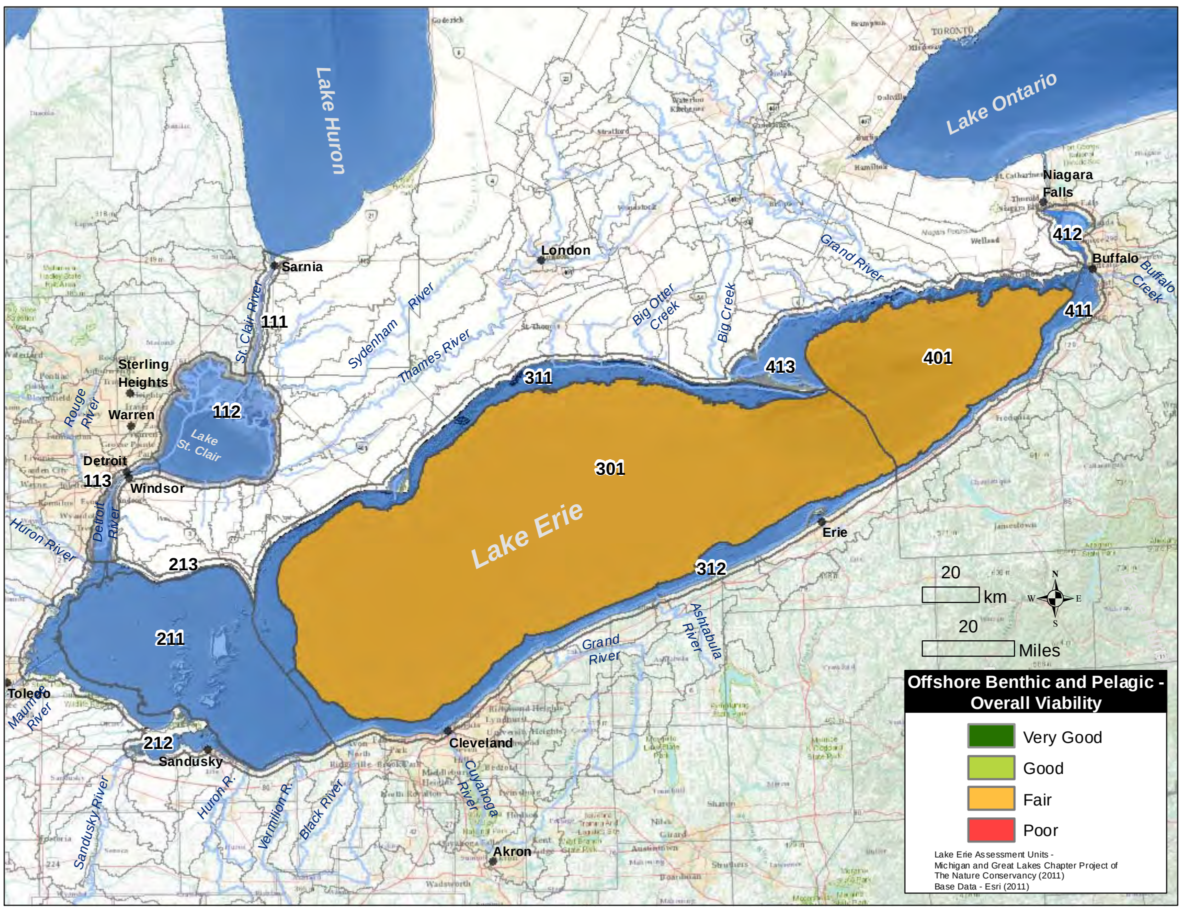

Figure 8: Viability of the Open Water Benthic and Pelagic Ecosystem at the assessment unit level.

4.3. Nearshore Zone

This target includes the submerged lands and water column of Lake Erie starting at 0 meters (shoreline) and extending to 15 meters in depth, including nearshore zones of islands, freshwater estuaries and excluding areas upstream from river mouths, and riverine coastal wetlands (Figure 9). The Nearshore is an important part of the lake for ecosystem productivity and diversity, species richness and economic uses (such as shipping and drinking water) and tourism (such as sport fishing and beaches).

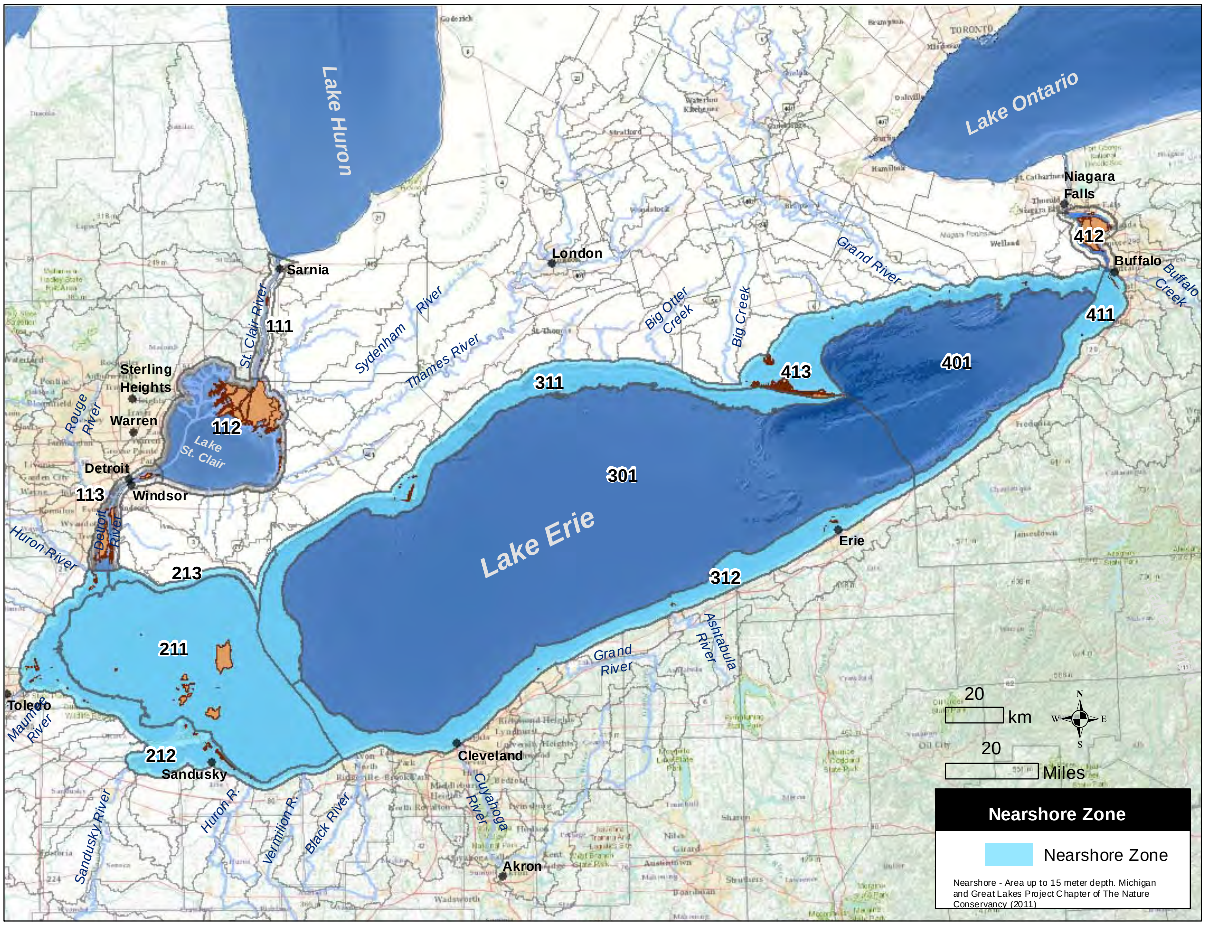

Figure 9: Distribution of the Nearshore Zone in Lake Erie.

Nested targets include: native submerged aquatic vegetation, shore birds, waterfowl, herpetofauna, benthic macroinvertebrates (e.g., *Hexagenia*), mussels, nearshore reefs and dependent species (e.g., walleye), and fishes (e.g., emerald shiner (*Notropis atherinoides*))

Human influences have been key factors in the lake's health for decades, with some problems reduced (e.g., sewage and industrial discharges), while others are emerging or even accelerating (e.g., increased dissolved phosphorus as a cause of algal blooms, invasive species, and climate change). The Western Basin comprises most of the Nearshore Zone area. This basin is the shallowest part of the lake and where the Nearshore has seen the most impacts. Algal blooms, supported by high levels of phosphorus, extended well into the Nearshore of the Central Basin in 2011 (Figure 10), extended far to the east, near Cleveland, Ohio, and hugged the northern shore in Ontario, including the Rondeau Provincial Park region (NOAA 2011). The spring flows and phosphorus loads "*explain the severity of cyanobacterial blooms in*

Lake Erie" and have been used to predict the algal bloom magnitude in August or later (Stumpf et al. 2012, p. 9). These blooms can alter ecosystem structure (Lopez et al. 2008). Phosphorus levels generally are increasing in all basins; they exceed targets in the Western Basin, and are at or above objectives thought to be critical for maintaining healthy fish populations (Forage Task Group 2011, 2012). Tourism provides billions of dollars each year for the local economy. Therefore, reducing algal blooms, which are unattractive at a minimum, and in some cases are toxic to people and pets (see below), is important for both the ecology and economy of the region.

Figure 10: NASA Moderate Resolution Imaging Spectroradiometer (MODIS) image of Lake Erie acquired October 9, 2011, showing an extremely large algal bloom (the green in the lake) extending well into the Central Basin. Some of the pale blue may be sediment http://earthobservatory.nasa.gov/IOTD/view.php?id=76115 [Accessed September 2012]

Lake Erie is the leading Great Lake for commercial and sport fishing, with most of the catch in the Nearshore Zone. Ontario's Lake Erie commercial fishery, primarily made up of yellow perch and walleye, accounts for about 80 per cent of the total value of the province's Great Lakes commercial fishery (OMNR 2012). Walleye and yellow perch are very highly sought-after sportfish and generate significant economic revenue in the Western and Central Basins. Smallmouth bass (*Micropterus dolomieu*) are a significant fishing attraction in the nearshore of Lake Erie. Levels of phosphorus found in the lake impact the fish community structure (Ludsin et al. 2001) and multi-year trends in species populations (Pers. comm., Roger Knight, ODNR, 2012) Considered eutrophic to hypereutrophic, current conditions in the

Western Basin *"favor a centrarchid (bass, sunfish) and cyprinid (carp, minnows) fish community instead of the desired percid (walleye, yellow perch) fish community*" (FTG 2012, p. 43). Key documents that guide fisheries management efforts in the Nearshore Zone of Lake Erie include the Strategic Vision of the Great Lakes Fishery Commission (GLFC 2011), the Lake Erie Fish Community Objectives (Ryan et al. 2003), as well as the annual reports of the GLFC's Forage Task Group (2011, 2012) and the Lake Erie Environmental Objectives (GLFC 2005). Alien invasive species such as round goby (*Neogobius melanostomus*) have long been established, and affect native fish through competition and as an egg predator. Asian carp (bighead (*Hypophthalmichthys nobilis*) and silver carp (*H. molitrix*) are established in the Mississippi drainage and threaten to cross into the Great Lakes system through such routes as the Chicago Sanitary and Ship Canal, and more directly to Lake Erie through routes such as the Wabash and Muskingum River watershed connections. Asian carp eDNA has been detected in the Lake, but viable populations are not known to have established themselves (MDNR 2012).

Perhaps the most outstanding issue for the Lake Erie Nearshore that has re-emerged is that of nutrient pollution and eutrophication, and resultant Harmful Algal Blooms (HABs). Blue-green algae are actually bacteria (cyanobacteria) and are the most common HABs. Some species can produce toxins that potentially impact the health of people and pets that come into contact with water. They can injure or kill fish and foul coastlines.

> "*There is a strong belief that allochthonous nutrient loading, especially (but not limited to) phosphorus, from urbanization and agriculture is a major contributor to the nuisance algae problem* (IJC 2011, p. 2)."

Consequently, as high loads and concentrations of phosphorus lead to nuisance algal blooms and HABs, ecosystems and biodiversity can be affected.

> "*Ecosystem impacts stemming from the effects of nontoxic, high biomass Cyano HABs are well documented (Fournie et al. 2008). Low oxygen events that suffocate and kill fish and bottom dwelling organisms are perhaps the most common adverse impact of high biomass blooms. In addition, high biomass blooms can block sunlight from penetrating into the water column, thereby preventing growth of beneficial algae. Food web crashes can also result due to the unpalatability and low food quality of many cyanobacteria, which can result in the starvation of consumers and their predators*" (Lopez et al. 2008, p. 14).

Ecological impairment by HABs can have many mechanisms. These include "*cell/tissue damage, growth inhibition, teratogenic, toxigenic (toxins, irritants, shading, allelopathic interactions, inadequate food quality, etc.* (Watson and Boyer 2011, p. 9)"

Nutrient loads to Lake Erie come from several sources, including municipal point sources, combined sewers, urban stormwater and agricultural sources. Lakewide phosphorus loads have not shown an increasing trend, and lakewide estimates have been near or below the target load set by the Great Lakes Water Quality Agreement since 1981 (Dolan and McGunagle 2005). Year-to-year variability in lakewide loads reflects the influence of weather on the tributary loads, as illustrated by the Maumee River, the largest contributor of tributary loads (Figure 11). These loads can be compared to phosphorus discharge trends from the Detroit Wastewater Treatment Plant (U.S. EPA 2009a). In recent years the increased loads of dissolved phosphorus from agricultural nonpoint sources, especially as measured discharging to the Western Basin from the Maumee and Sandusky Rivers, have been associated with increased blooms of cyanobacteria, particularly *Microcystis*, in the Western Basin (extending into the Central Basin in 2011), and extensive nuisance growth of *Cladophora*, an attached filamentous alga, in many nearshore areas. Past blooms of cyanobacteria were dominated by *Anabaena* and *Aphanizomenon*, but the abundance of *Microcystis*, often responsible for toxic blooms, has increased in recent years. A complicating factor is the recirculation of nutrients by dreissenid mussels, thought to have altered nutrient cycling in the lake (Hecky et al. 2004).

Cladophora does not result in HABs since it does not produce toxins, but is considered a nuisance algae since its extensive growth in the shallow nearshore of Lake Erie contributes to the *Poor* status of many areas (Howell et al. 2011). The nuisance growth and subsequent die-off of *Cladophora* decreases aesthetic value of the nearshore waters (e.g., beach fouling) and causes degradation of nearshore habitat. Dreissenid mussels have increased lake transparency and have been linked to the resurgence of *Cladophora* blooms, which have been at nuisance levels in much of the relatively rocky shores of the Eastern Basin. There has been significant interest in these blooms since the late 1990s. It colonizes nearly 100% of the available substrate and recent blooms have been comparable to the nuisance growth levels of the 1970s (Higgins et al 2005; Auer and Bootsma 2009). Lowering of basin-wide lake phosphorus levels could lead to reduction in *Cladophora* areal coverage (Auer and Bootsma 2009; Auer et al. 2010).

Dissolved and particulate phosphorus forms comprise total phosphorus, and about 30% of the particulate is bioavailable. Most of the dissolved phosphorus occurs as dissolved reactive phosphorus, which is 100% bioavailable. Heidelberg University's Lake Erie tributary monitoring has documented the increases in the load of dissolved phosphorus (Figure 12) since the mid-1990s (Richards et al 2007). The result has led to an "*urgent need now for coordinated and strategic nutrient management actions*" to improve the quality of the Nearshore (U.S. EPA 2011, p. 2). As a result of the Great Lakes Water Quality Agreement, concentrations of total phosphorus have been recommended for the basins of Lake Erie as "*Total phosphorus concentrations in surface waters indicator endpoints"* (U.S. EPA 2009b, p. iv, 3). Targets for total phosphorus concentrations for the Nearshore have been established at 20 ug/L, and at 15 ug/L for "Offshore" in the Western Basin (Lake Erie LaMP 2011). (Note: These LaMP "nearshore" and "offshore" terms differ from those used in this document.) More recently, the Great Lakes Water Quality Agreement of 2012, Annex 4 (IJC 2012), states an "Interim Substance Objective for Total Phosphorus Concentration in Open Waters" of 15 ug/L in the Western Basin of Lake Erie. The GLWQA of 2012 also includes" (1) "Substance Objectives" to set phosphorus concentrations for nearshore waters; and (2) open waters objectives of 10 ug/l for the central and Eastern Basins.

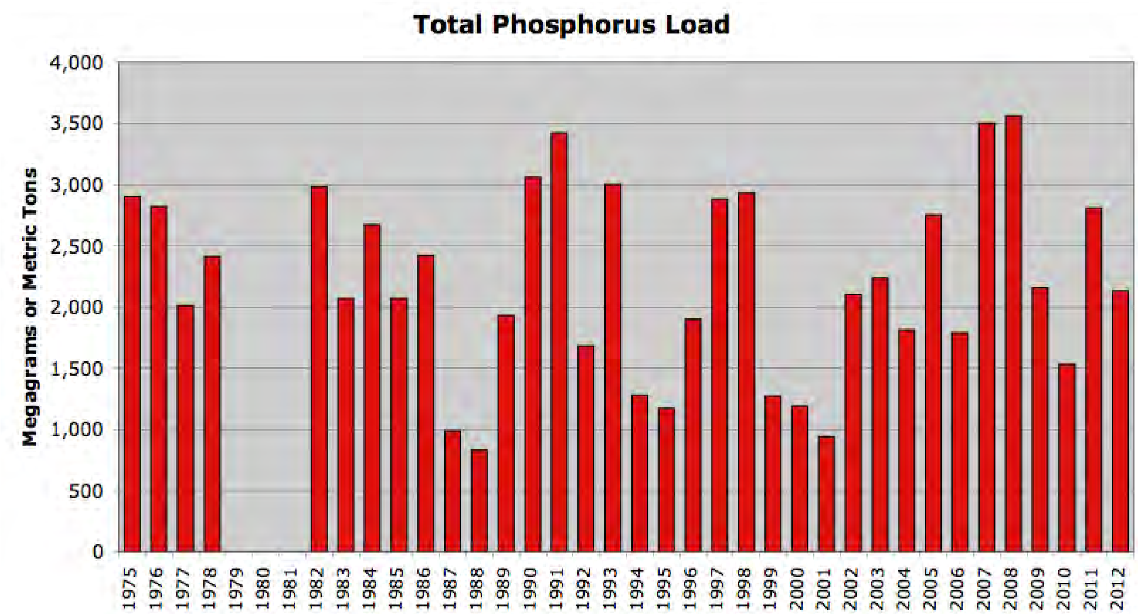

Figure 11: Maumee River (as measured at Waterville, Ohio) total phosphorus load annual (water year) trends. Provided August 2012 by R. Peter Richards, produced from Heidelberg University data.

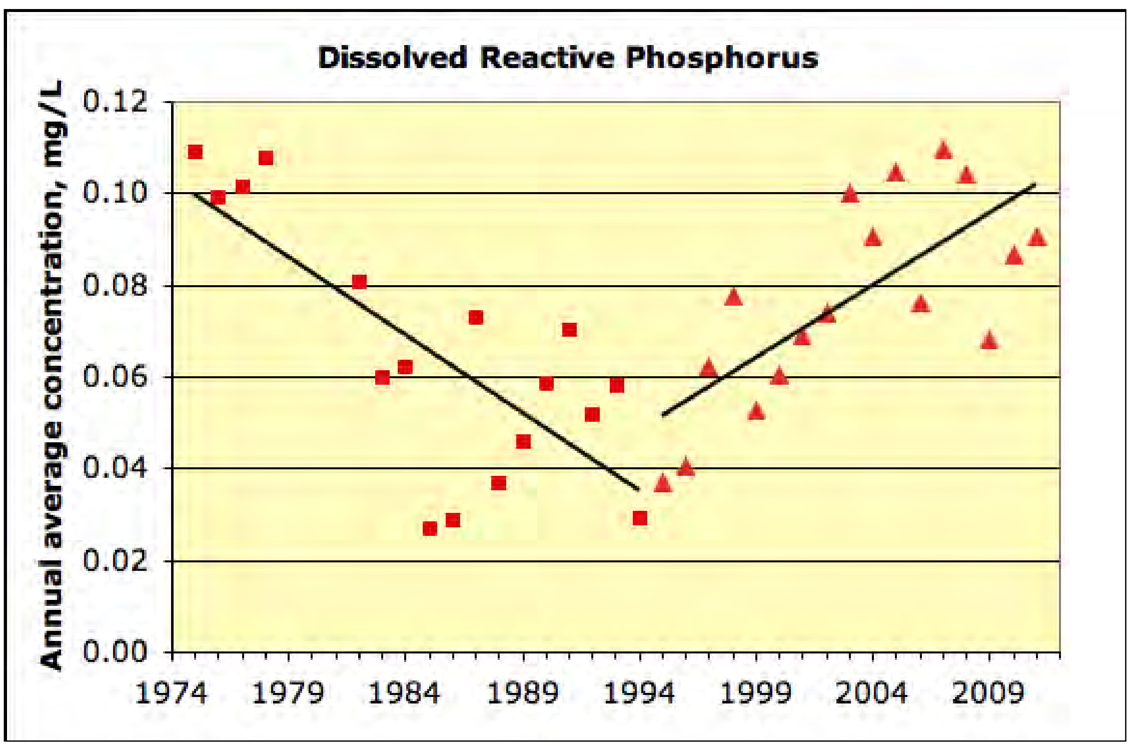

Figure 12: Maumee River (as measured at Waterville, Ohio) DRP trends based on annual (water year) flow-weighted mean concentrations. Provided August 2012 by R. Peter Richards, produced from Heidelberg University data.

The relationship between total phosphorus, including dissolved and particulate, and algae as indicated by chlorophyll has been demonstrated and remains strong. Reductions in the amount of phosphorus discharged to Lake Erie are needed; "*the Great Lakes Water Quality Agreement goals and targets are not consistently being met* "(U.S. EPA 2009b, p. 1). The exact result in lake concentrations resulting from a reduction in phosphorus loading is not clear, however based on past conditions of the lake, there has been a call for significant load reductions:

> "*Phosphorus reduction programs led to improved conditions until the late 1990s, when bottom water hypoxia returned to preaction levels, with increases in nonpoint sources pinpointed as the most likely cause*" (U.S. EPA 2011, p. 3).
>
> "*While total P (phosphorus) loading has not increased significantly in the last 15 years, the loading of dissolved P is back to the levels of the early 1970s, and it is possible that a 2/3 reduction in the current loading of dissolved P will again be required to control the problem*" (Reutter et al. 2011, p. 4).

It is important to note that because the lakewide phosphorus load is largely determined in the Western Basin and much of that phosphorus also reaches the central and Eastern Basin, the loads and concentrations in the Western Basin determine a significant portion of the phosphorus-related health of most of Lake Erie. The lakewide loads are expected to have far-reaching effects; strategies and efforts to reduce phosphorus loads in the Western Basin should show results in these other areas. Additional efforts to address significant localized impacts are still expected.

Lake Erie's native mussels were historically abundant and rich in diversity, supporting a rich mussel fauna of about 35 species (Nichols and Smith 2009). However, this community has experienced a major decline over the decades, most likely due to water quality (Nalepa et al. 1991) and the dreissenid invasion (zebra and quagga) mussels (Schloesser et al. 2006). Metcalfe-Smith et al. (2002) documented the lakewide species decline. Crail et al. (2011) suggest that conditions may be improving for native mussel species. A recent native mussel survey, including genetic analyses, was completed across the U.S. nearshore area (Pers. comm., D. Zanatta, Central Michigan U., 2012). Dreissenid densities and biomass are considered high in much of Lake Erie, with most biomass in the Eastern Basin. "*Recent surveys (2005-2010) in the western basin indicate that dreissenid populations have fluctuated from year-to-year with no clear trends, and that quagga mussels have replaced zebra mussels as the dominant species*" (Nalepa et al. 2011, p. 2.)

As described in more detail in Appendix H, many climate-related stressors have the potential to directly, or indirectly influence the viability of the Nearshore. As a target that integrates terrestrial and aquatic systems, the Nearshore has the potential to be impacted particularly strongly by temperature increases (in shallow waters, and in stream or overland flow), and as a result of increases in storm intensities, and associated increases in run-off, including run-off that carries phosphorus into the system. These changes can influence energy flow and nutrient loading within the system, and can further promote algal blooms, and anoxic conditions. While changes in habitat availability are the only climate change threat that was individually ranked in our assessment, these other impacts were considered during strategy development.

Figure 13 *Microcystis* bloom in Lake Erie near South Bass Island, August 5, 2009. Photo by: Ohio Sea Grant.

Nearshore Zone Goal

By 2030, to assure adequate water quality for sustaining native plants, fish, and invertebrates:

Based on multi-year averages, reduce the load of dissolved phosphorus by 50% by 2030 in at least the priority watersheds. HAB toxin measures will be reduced to the point that no HAB advisories at public beaches will be recorded and issued. The native fish community will have abundant populations of native species, including: smallmouth bass, largemouth bass (*Micropterus salmoides*), northern pike (*Esox lucius*), muskellunge (*Esox masquinongy*), rock bass (*Ambloplites rupestris*), emerald shiners (*Notropis atherinoides*), white sucker (*Catostomus commersoni)*, *Cyprinids*, walleye and yellow perch.

4.3.1. Viability of the Nearshore Zone

The Nearshore Zone in Lake Erie has an overall viability of *Fair* (see Appendix E for details). Based on the indicators for which we have values, each assessment unit also scored a *Fair* ranking (Figure 14), but there is significant variation among units with regard to individual indicators. For example, the northern shore of the Eastern Basin (unit 413) was ranked *Good* for yellow perch population, bed load traps and groins, and total phosphorus concentration, and Lake St. Clair (unit 112) also achieved a *Good* rank for its high scores on bed load traps and groins and erosion and deposition rates from tributaries (Appendix E). In contrast, the Western Basin, which is generally considered the most degraded portion of the lake, shows the most modification under the Artificial Shoreline Hardening Index and the lowest percentages of natural land cover in the watershed. Western Basin units also score poorly for yellow perch population and total phosphorus concentration, and only the ratings for bed load traps and groins (*Good* for unit 211 and *Very Good* for unit 213, which is the central portion of the basin) rise above a *Fair* rank. Based on this assessment, the Western Basin is the most degraded portion of the lake, with conditions generally improving toward the east. The Central Basin is affected by pollutant loads, particularly phosphorus, which enters predominantly from the Western Basin. Phosphorus is the primary pollutant leading to massive blue-green algae blooms and extensive anoxic conditions, which are a major threat to ecosystem health and tourism. Recent high dissolved phosphorus loads, as shown by tributary monitoring by Heidelberg University, and heavy algal blooms have coincided with multi-year declines in the harvest of sport fish such as walleye. Phosphorus concentrations exceed Lake Erie Fish Community Ecosystem Targets (GLFC 2005, Forage Task Group 2011, 2012) and have led to hyper-eutrophic conditions in the western basin. Invasive species have negative impacts on natives, such as the displacement of native mussels by Dreissenid species, while others, such as the round goby, now are a predominant part of the biomass and displace many native fish.

Goals:

As an outstanding feature of the condition of Lake Erie's Nearshore, algae, including Harmful Algal Blooms[7] and *Cladophora*, could be used as a measure of the response to nutrient loads and the health of the Lake. Among the "placeholder" indicators of water quality using HAB and *Cladophora* measures that should be addressed by the LaMP in the near future are:

- Areal extent of HABs as measured by NOAA satellite data.
- Concentration of HABs in Lake water (such as through measurements comparable to those conducted by the University of Toledo).
- HAB toxin measures will be reduced to the point that no HAB advisories at public beaches will be recorded and issued.
- HAB toxin concentrations in intakes at public drinking water treatment plants.
- Areal extent and weight of standing crop of *Cladophora.*

Another goal for consideration could incorporate the areal extent of submerged aquatic macrophytes (see "Emergent and submergent vegetation distribution in protected embayments and soft sediment areas" in Appendix F for more information).

[7] In general, this document refers to "Harmful Algal Blooms" as those composed of cyanobacteria ("blue-green algae"). Cyanobacteria blooms can be harmful, but are not always harmful since the algae do not always produce toxin. Similarly, not all HABs are cyanobacteria. Measures of success will need to clearly establish which categories of algae are included.

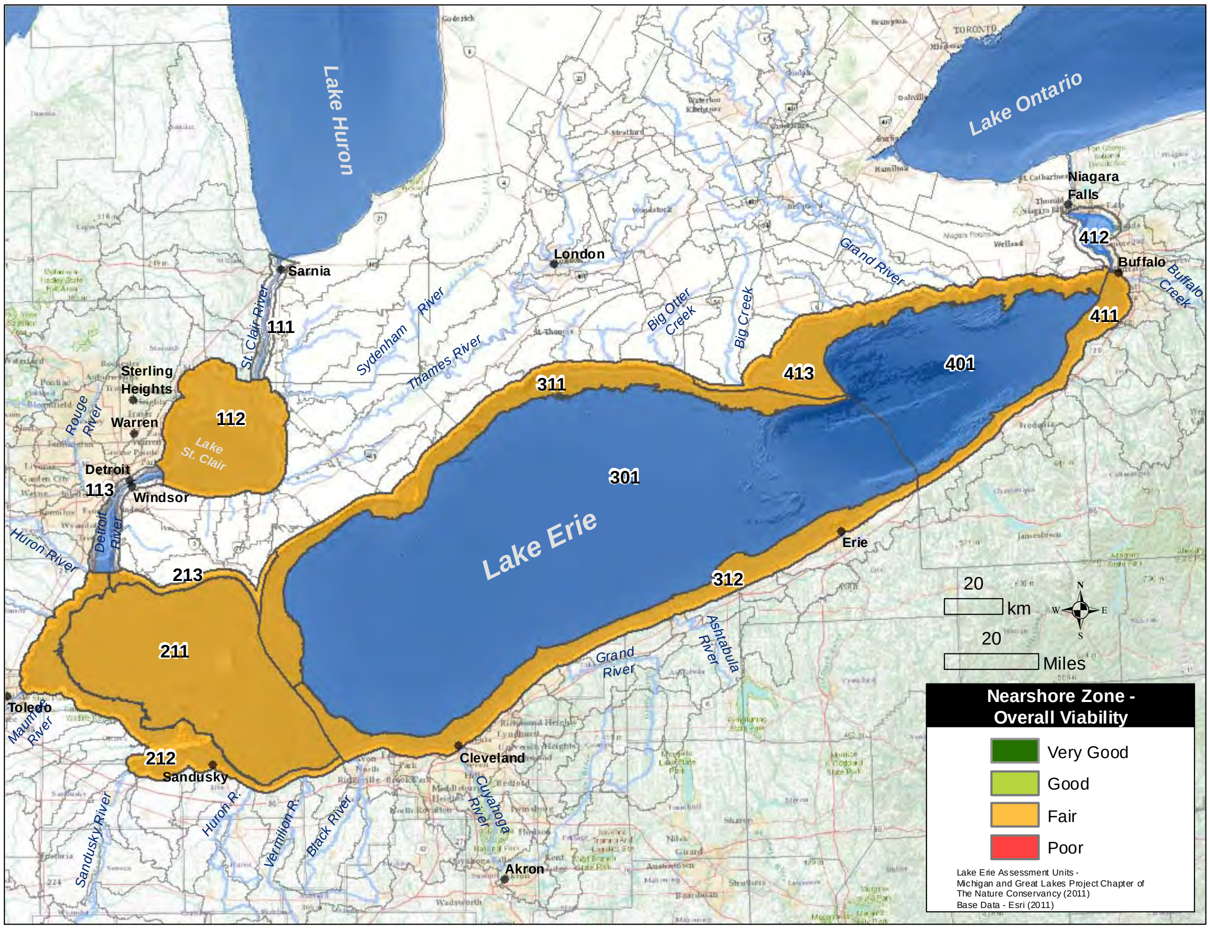

Figure 14: Viability of the Nearshore Zone at the assessment unit level

4.4. Native Migratory Fish

The Native Migratory Fish biodiversity conservation target includes native Lake Erie fishes that migrate to and depend on tributaries as part of their natural life cycle—usually for spawning, but sometimes for foraging or refugia (e.g. thermal, predation). These fishes include Lake Erie fishes that spawn almost exclusively in rivers, such as lake sturgeon (*Acipenser fulvescens*) or shorthead redhorse (*Moxostoma macrolepidotum*), as well as species that spawn in both lake and riverine habitats, such as walleye or white sucker. Many different Great Lakes fish species migrate into tributaries, including at least 30 species in Lake Erie (Trautman 1981, Herbert et al. 2012). While these fishes spend a portion of their life in Nearshore, Coastal Wetland, or Offshore Zone (which are conservation targets in this plan), they are identified as a specific target because: 1) these species play important roles in the ecology of Lake Erie (Knight and Vondracek 1993) and important part of their life takes place in tributaries, 2) they provide important functional ties between the Great Lakes and their tributaries (Flecker et al. 2010, Childress 2010), and 3) they aid in the migration of other native organisms between the Great Lakes and their tributaries such as mussels (Sietman et al. 2001, Woolnough 2006, Crail et al. 2011). Native Migratory

Fish are diverse and provide a variety of important contributions to Lake Erie fisheries, including sport fish (e.g. walleye) and forage fishes (e.g. emerald shiner).

Nested targets include: lake sturgeon, walleye, suckers, sauger.

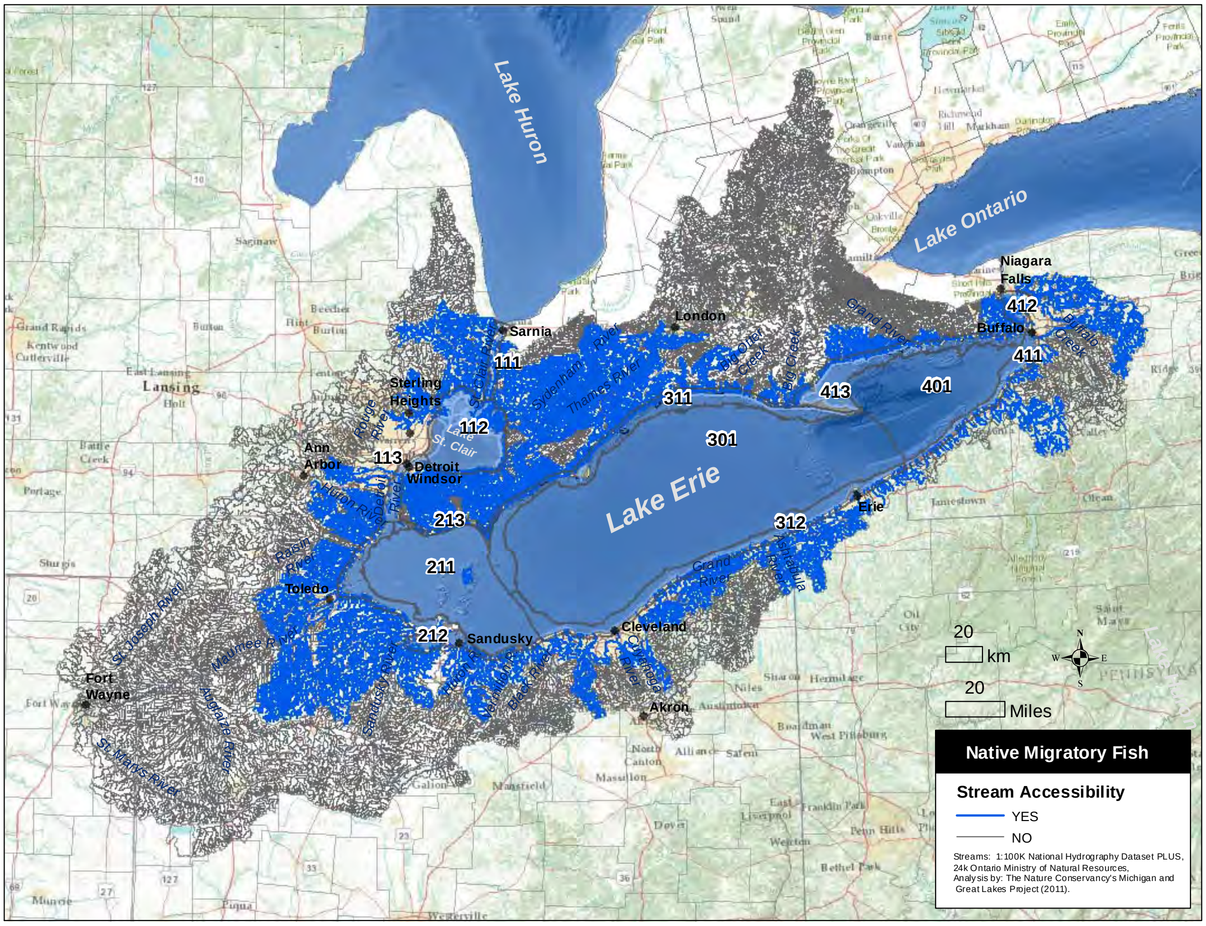

Figure 15: Stream accessibility for Native Migratory Fish in Lake Erie

Native Migratory Fish populations are highly imperiled in Lake Erie due to habitat degradation and loss of access to riverine habitat. Sauger and lake sturgeon were historically both very important commercially in Lake Erie, but sauger are now virtually extirpated from Lake Erie and lake sturgeon only successfully spawn in the Connecting Channels, with no known spawning populations in Lake Erie tributaries. Several other migratory fishes are now rare in Lake Erie and most have experienced significant (>50%) population reductions. This loss results in changes in the community structure of the nearshore and alters the functional relationships between Lake Erie and its tributaries.

Native Migratory Fish Goal

By 2030, to provide adequate access to spawning habitat:

- At least 50% of the total length of each type of stream is connected to the lake;
- Each river-spawning Lake Erie fish species is represented by at least two viable populations in each applicable region (i.e. assessment unit) of the lake.
- Tributary connectivity is maximized for Lake Erie migratory fish, while increased risk of aquatic invasive species spread and proliferation is minimized.

4.4.1. Viability of Native Migratory Fish

The Native Migratory Fish target in Lake Erie has a viability of *Fair*, overall (see Appendix E for details). But there is significant variation across assessment units. While most assessment units are rated as *Fair*, the northern shoreline of the Western and Central Basins and the Detroit River have a status of *Good* for Native Migratory Fish based on indicators of connectivity and fish populations (Figure 16). For the northern shoreline of the Central Basin and the Detroit River, most habitat connectivity indicators and fish population indicators were also rated as *Good*. But for the northern shore of the Western Basin, the *Good* rating is largely attributable to *Very Good* habitat connectivity, because most fish population indicators were ranked below *Good*. Conversely, the northern shoreline of the Eastern Basin and the south and western shoreline of the Western Basin are in *Poor* condition. These assessment units had *Poor* connectivity (<25%) across tributary habitats, but they also rated *Poor* for most fish population indicators.

Given the importance of temperature-related factors to fish biology, climate change is also an important consideration when assessing the future viability of Migratory Fish. While the waters of Lake Erie are relatively well buffered from temperature increases, especially in the deeper Eastern and Central Basins, streams, warming of nearshore waters and the Western Basin could potentially lead to changes in the timing of migration, or to higher rates of energy use during migration if timing does not change. In extreme cases, and when combined with anoxic conditions, warmer waters in the Western Basin can lead to rapid death of fish, including migratory species (see Appendix H).

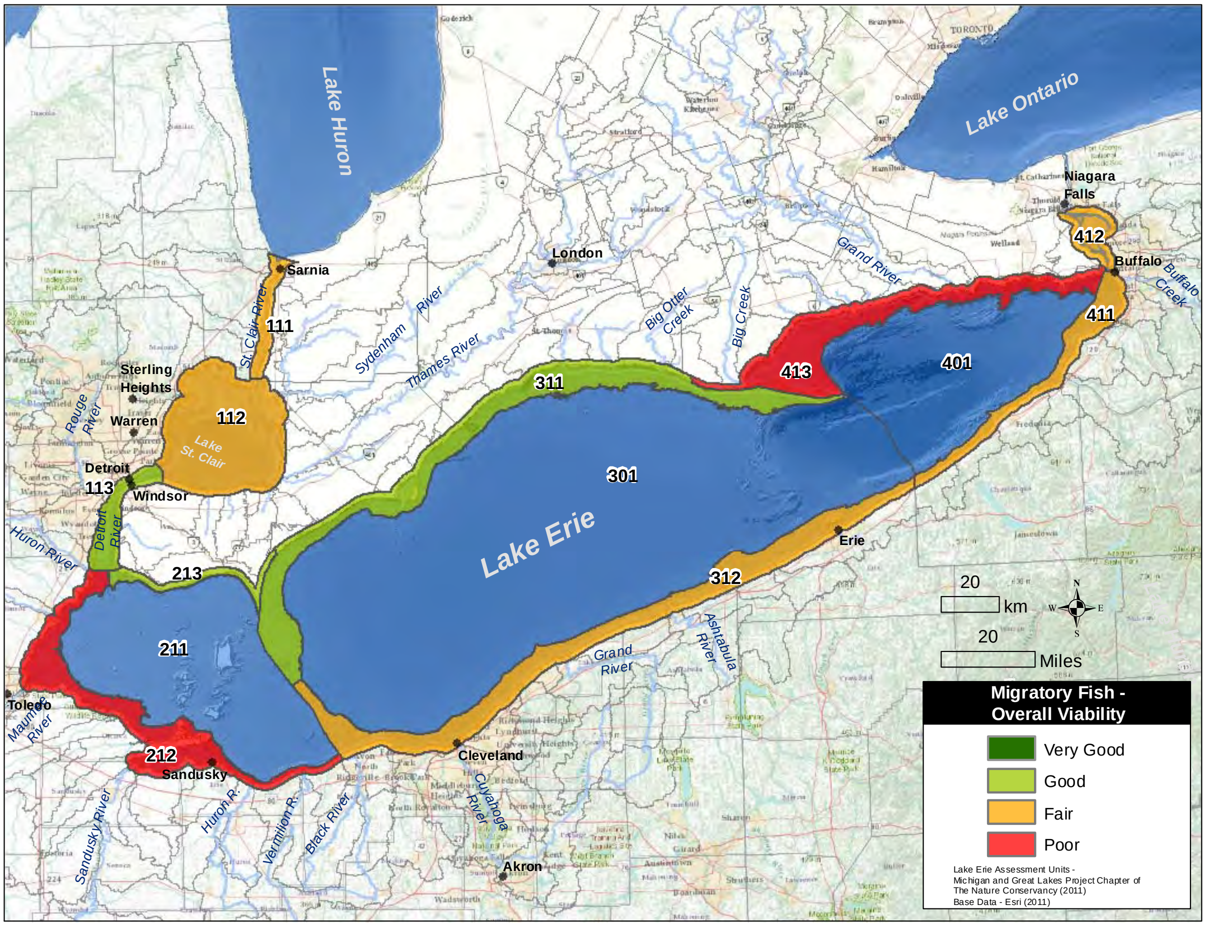

Figure 16: Viability of Native Migratory Fish at the assessment unit level.

4.5. Coastal Wetlands

Great Lakes Coastal Wetlands provide numerous functions including habitat, nutrient and sediment processing and retention, buffering of wave energy, ant others, and as such are extremely important ecosystems in all of the Great Lakes. They are dynamic, in that vegetation zones move lakeward or onshore in response to decadal-scale changes in water levels, and native species are also adapted to seasonal and annual variation in water levels. As habitat, they are critical for spawning and larval fish, breeding and migratory birds, invertebrates, herptiles, and mammals, and are considered to have the highest species diversity of any Great Lakes ecosystem. As described by The Nature Conservancy (TNC, 1994, p 33):

> *"Much of the biological productivity and diversity in the Great Lakes aquatic ecosystem is concentrated in the coastal zone, especially the coastal wetlands. Freshwater marshes play a pivotal role in the aquatic ecosystem of the Great Lakes, storing and cycling nutrients and organic material from the land into the aquatic food web. They sustain large numbers of common or regionally rare*

bird, mammal, herptile and invertebrate species, including many land-based species that feed from the highly productive marshes. Most of the lakes' fish species depend upon them for some portion of their life cycles (Whillans 1990), and large populations of migratory birds rely on them for staging and feeding areas."

For the purposes of the LEBCS, the Coastal Wetlands conservation target includes all types of hydrogeomorphic wetlands (lacustrine, riverine, palustrine, and subcategories including barrier protected, estuaries and island coastal wetlands) with historic and current hydrologic connectivity to, and directly influenced by Lake Erie (Albert et al. 2003) (Figure 17).

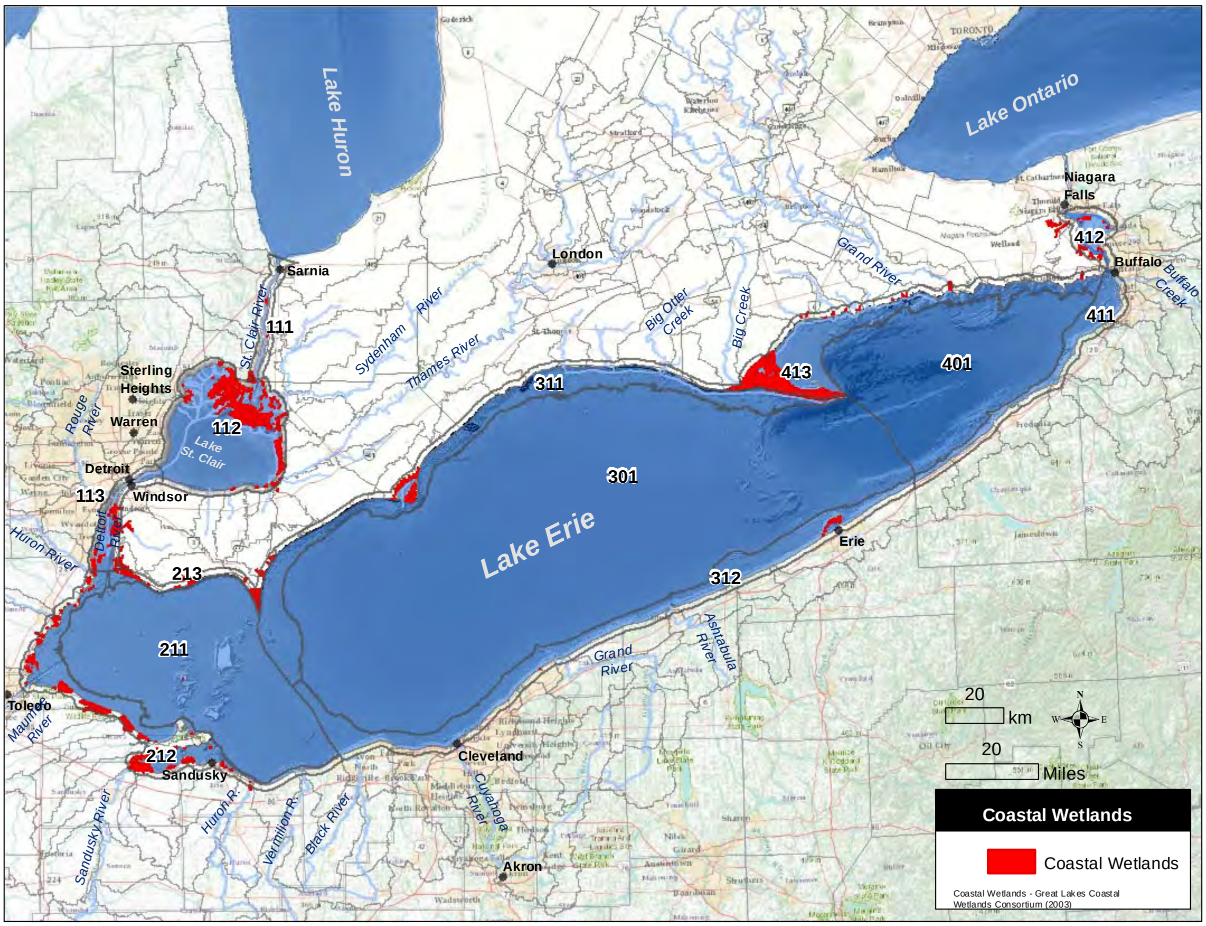

Figure 17: Distribution of the Coastal Wetlands in Lake Erie.

Nested biodiversity targets include: emergent marshes, wet meadows, sedge communities, submergent/emergent/floating native aquatic plants, migratory waterbirds, wetland obligate nesting birds, herpetofauna, wetland dependent fishes, aquatic macroinvertebrates and mussels.

In Lake Erie, Coastal Wetlands formerly occurred throughout the lake but were especially abundant in the Western Basin, Lake St. Clair, and along the shores of the Detroit River, St. Clair River, and the Upper Niagara River. In many of these areas, wetland losses have been significant, sometimes in excess of 95%

(e.g., Detroit River; Manny 2007). Similarly, the Upper Niagara River was once lined by Coastal Wetlands (Buffalo Niagara Riverkeeper 2012), but now over 75% of the shorelines are artificially hardened (GLEAM 2012).

Substantial and highly diverse Coastal Wetlands remain in the Lake Erie basin, with prime examples at Long Point, Rondeau Coastal Wetlands, Dunville Marshes at the mouth of the Ontario Grand R ,and Point Pelee in Ontario; Lake St. Clair (Ontario and Michigan), and in several public and private wetlands in the Western Basin, many of which are diked. Though reduced in size and in some cases only partially connected to the lake, these wetlands still serve many important functions and efforts are underway to expand, restore, and reconnect many of these wetlands.

Achieving goals for Coastal Wetlands condition and area may be complicated by the impacts of climate change, which may influence lake levels through impacts on ice cover, evaporation rates, and run-off from land. While current projections of future lake levels suggest ranges of variation that are within the range of historic levels (see Appendix H), updates in projections are likely as new climate projections emerge, and as hydrologic models are updated. Further, short term variation may not be well reflected by long-term trends assessed by models. Due to their location, coastal wetlands are likely to be at risk from increased run-off, which is predicted to result from increases in peak storm intensities. This elevated risk emphasizes the importance of restoration of wetlands as they can help protect coastal communities from storm surges, which are also likely to increase in intensity as storm intensities increase.

Coastal Wetlands Goal

By 2030, so that Coastal Wetlands provide adequate ecological functions and habitat for native plants and animals:

- The average wetland macrophyte index for Coastal Wetlands around the lake will reflect good condition;
- Coastal Wetland area around the lake will have increased by 10% compared to the 2011 wetland area.

4.5.1. Viability of Coastal Wetlands

To assess viability of Coastal Wetlands, we were somewhat limited by the availability of data. There has been substantial work to develop a shared set of indicators through the Great Lakes Coastal Wetland Consortium (http://glc.org/wetlands/), and an ongoing project funded by the Great Lakes Restoration Initiative is undertaking surveys across the Great Lakes basin following these protocols (e.g., Uzarski et al. 2004, 2005). Data from these surveys, now in their second year, are not yet fully available. Our viability assessment incorporates only the ratings for the invertebrate IBIs. The project team is developing an online application for the reporting and input of wetland data and plan to activate that application in 2013 (Matthew Cooper, Notre Dame University, pers. comm.). The viability assessment of Coastal Wetlands should be updated as those data become available.

Our assessment benefitted from very recent mapping of *Phragmites* coverage completed by Michigan Tech Research Institute (2012) in another GLRI funded project in cooperation with USGS and the USFWS. We were provided data from this project, which enabled us to assess *Phragmites* coverage in most of the Coastal Wetlands around Lake Erie.

Overall, the current status of Coastal Wetlands in Lake Erie is *Fair*, which suggests that there is real cause for concern and that some individual wetlands may be beyond hope of restoration, but that some are in good shape and many may be restorable with sufficient effort. Most of the assessment units are also in *Fair* condition, though two have a *Good* status, including 111 (St. Clair River) and 312 (U.S. coast of the Central Basin; Figure 18). Unit 111 is distinguished by better than average ratings for nested natural communities and wetland area; unit 312 also scored well for nested natural communities or species and also relatively high Amphibian IBI scores; wetlands in unit 413—which includes Long Point—scored well on nested natural communities and species targets, Wetland Fish Index, and the Water Quality Index (see Appendix E for details), though the overall rank for unit 413 remained *Fair*. This unit also contains some wetlands, such as the Dunnville Marshes at the mouth of the Grand River, that are degraded and represent opportunities for enhancement. Unit 113—the Detroit River—received *Poor* ranks for altered shorelines and land cover within the watershed and coastal areas, as well as generally low scores on the indicators that have been evaluated.

As should be expected in an altered system, the status of key ecological attributes and indicators for Coastal Wetlands vary across Lake Erie (Appendix E). For example, amphibians and birds in Coastal Wetlands are generally in *Poor* to *Fair* condition, with a couple of exceptions, whereas the EO ranks of natural communities generally reflect *Good* to *Very Good* condition (recognizing that data for this indicator is incomplete). Connectivity of wetlands, as indicated by percent natural land cover in watersheds, is universally in *Poor* status. Increasing attention to restoration and monitoring of wetlands—both of which are ongoing now—should improve our understanding of these vital ecological systems and their overall condition.

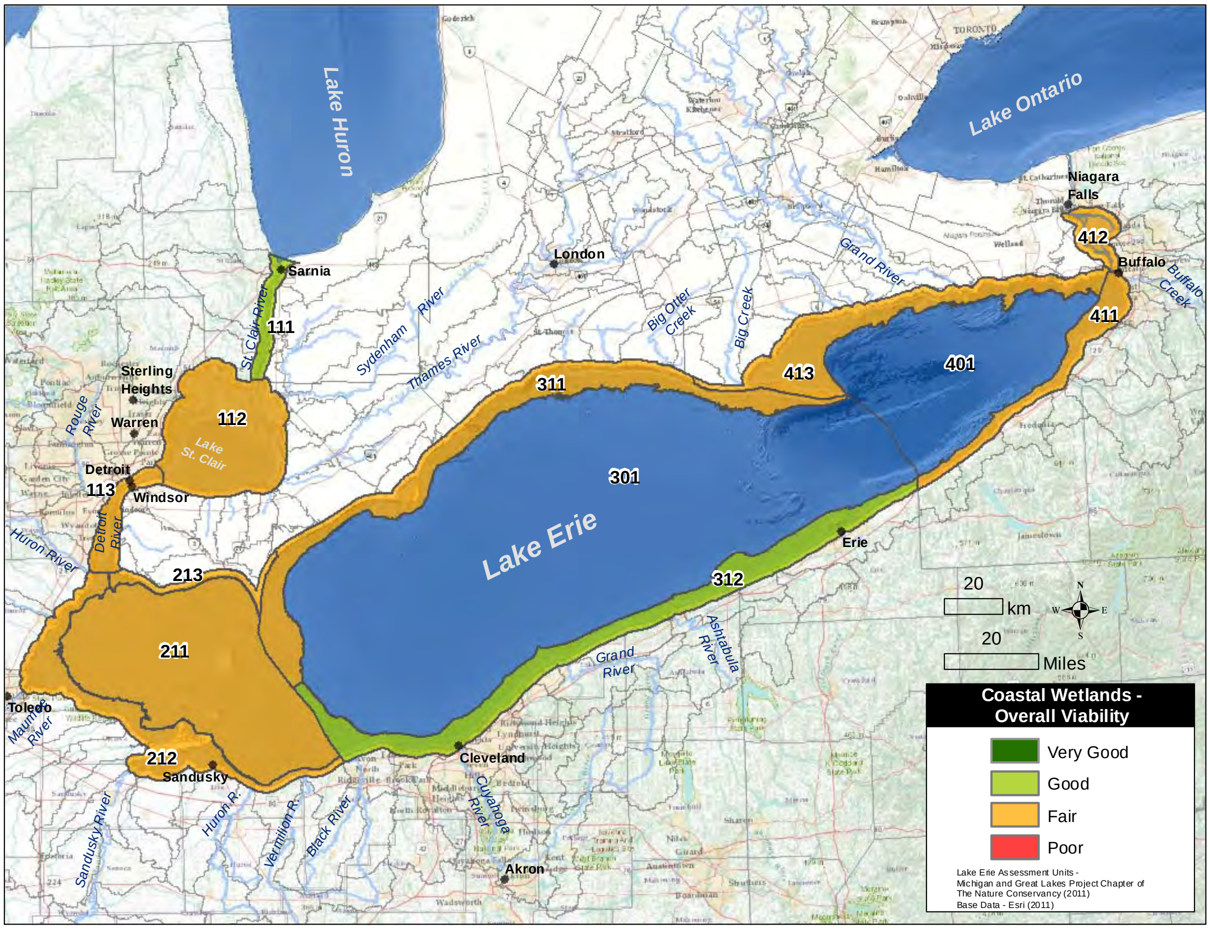

Figure 18: Viability of Coastal Wetlands at the assessment unit level.

4.6. Lake Erie Connecting Channels

This biodiversity conservation target encompasses the waterways that connect Lake Erie with adjacent Great Lakes, including the St. Clair River, Lake St. Clair, the Detroit River, and the Upper Niagara River above Niagara Falls. These waterways provide both unique habitats, such as large streams with fast flowing waters, as well as important connections to Lake Erie. Historically, they have been among the most heavily altered of Great Lakes systems; five of the twelve Areas of Concern (AOCs) in Lake Erie are located on these Connecting Channels and their associated tributaries. This high level of impact reflects the importance of these channels not only to biodiversity but to people—they are among the most heavily populated and industrialized areas of the Great Lakes.

Nested targets: Huron – Erie Corridor, Upper Niagara River (above Niagara Falls), freshwater mussels, big river fishes (e.g., mooneye, lake sturgeon).

The Upper Niagara River stretches roughly 34 km from the outlet of Lake Erie to Niagara Falls, and contains approximately 14 islands, the largest, Grand Island, is over 10,000 acres. Over 80 species of fish have been recorded from the River (upper and lower) Buffalo Niagara Riverkeeper 2012), several of which are now quite rare or have even been extirpated. Historic dredging, blasting, and industrial use have degraded many of the attributes of the river, and the entire river is an AOC. Contaminants have been one of the most critical causes of impairments in the Niagara River, but over the last two decades 18 of the worst contaminants have decreased by over 90% (Wooster and Matthies 2008), with a corresponding decrease in toxics in herring gull (*Larus argentatus*))eggs (Environment Canada 2007). Shoreline hardening is another key threat - over 65% of shoreline of the Niagara River is artificial. The U.S. side of the entire river is armored (Wooster and Matthies 2008), and over 75% of the Upper River (both sides) in hardened condition (NOAA 1997). These threats have greatly reduced or impaired Coastal Wetlands and nearshore habitats for fish, aerial migrants, and many other species. The Huron – Erie Corridor (HEC), consisting of the St. Clair and Detroit Rivers and Lake St. Clair, contains nearshore and stream habitats, as well as extensive Coastal Wetlands. Lake St. Clair harbors over 30,000 acres of wetlands, and the Detroit River has over 4,000 acres (Great Lakes Coastal Wetland Inventory 2004), though this total represents over 90% loss for the Detroit River (Manny 2007). Over 65 species of fish, 16 of which are threatened or endangered, use the HEC (Huron – Erie Corridor Initiative 2012). The HEC is also part of the central Great Lakes flyway for millions of migratory birds and is recognized as part of a globally significant shorebird stopover area.

Future viability and the potential for positive change in indicators for Lake Erie Connecting Channels in response to conservation strategies may be influenced by several aspects of climate change. As air temperatures continue to increase, related increases in water temperatures may reduce the habitat quality of these sites for some species. Similarly, stormwater entering these systems from urban areas is likely to be warmer over time; in some locations these systems are also exposed to releases of warm waters that have been used in some form of industrial cooling process. Climate-related changes in lake level, while currently quite uncertain (discussed in more detail in Appendix H) are also important considerations; drops can lead to increased dredging, and increases can reduce wetland acreage, especially in areas with highly developed or hardened shorelines. Further, expected continued increases in the intensities of peak storms can overwhelm stormwater and sewage handling systems, leading to a higher frequency of overflows that reduce water quality.

Lake Erie Connecting Channels Goal

By 2030, so that Lake Erie Connecting Channels continue to improve as critical habitat for the full diversity of native species:

- Shoreline hardening is below 50% along both shores;
- Coastal wetlands in the Detroit River comprise at least 25% of historic area;
- At least one viable refuge for native mussels persists in each connecting channel;
- Spawning of river-spawning migratory fish continues to show an improving trend

4.6.1. Viability of Lake Erie Connecting Channels

The viability assessment of the Lake Erie Connecting Channels is based on incomplete information, and we have current status ranks for only some of the indicators identified by experts (see Appendix E). The Detroit River seems to be particularly well studied, and the St. Clair River and Lake St. Clair somewhat less so; the Upper Niagara River (assessment unit 412) seems to be less well known. Of the indicators that have been rated, some, such as shoreline hardening, are *Poor* in all assessment units, whereas others are mostly in the *Fair* to *Good* range. The only indicators that have *Very Good* status—for which data are available only for the HEC—are the number of mature lake sturgeon and dissolved oxygen concentration.

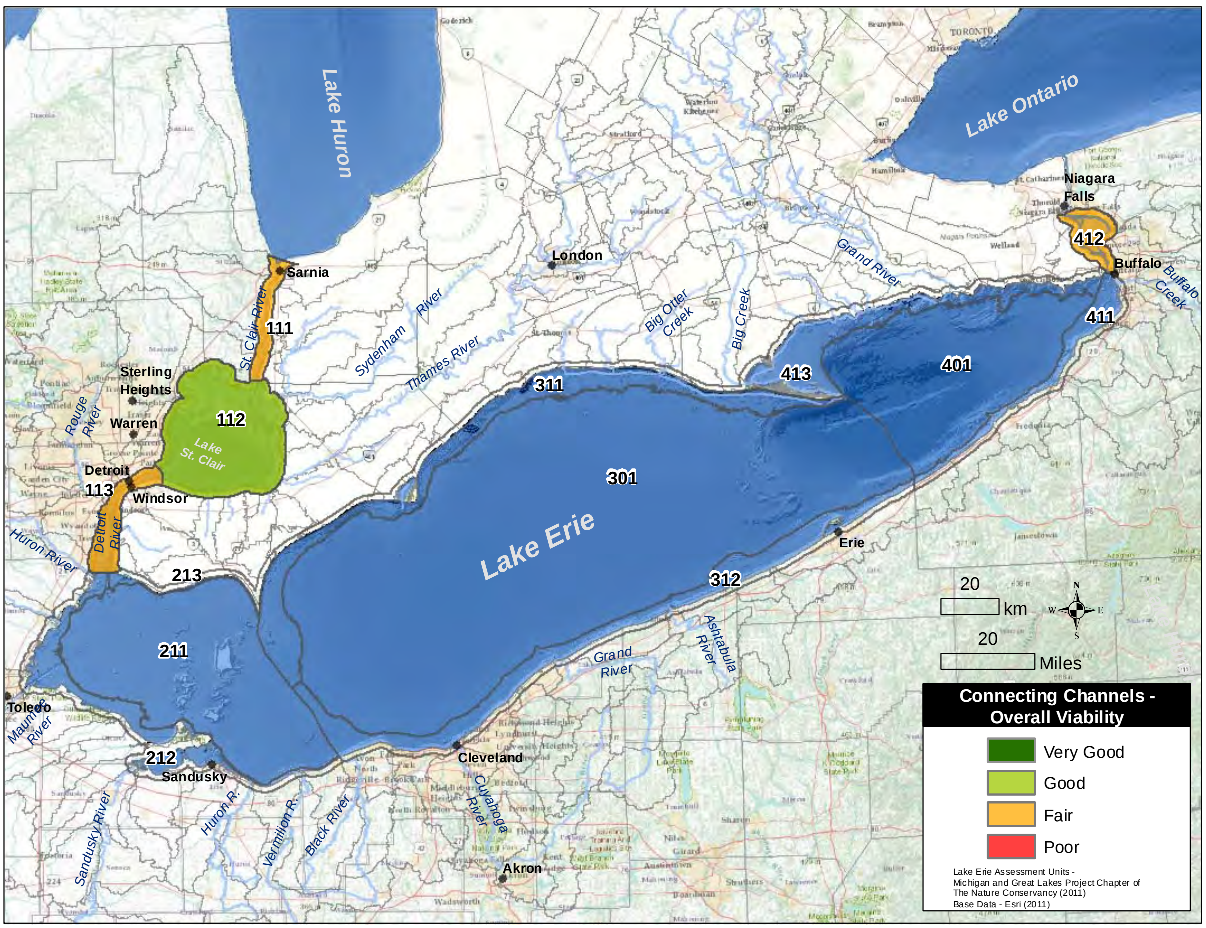

Figure 19: Viability of Connecting Channels at the assessment unit level.

4.7. Islands

Islands comprise all land masses within Lake Erie that are surrounded by water, including both naturally formed and artificial islands that are 'naturalized' or support nested targets. There are over 2,100 islands in the Huron-Erie corridor, Lake Erie and Niagara River (Figure 20).

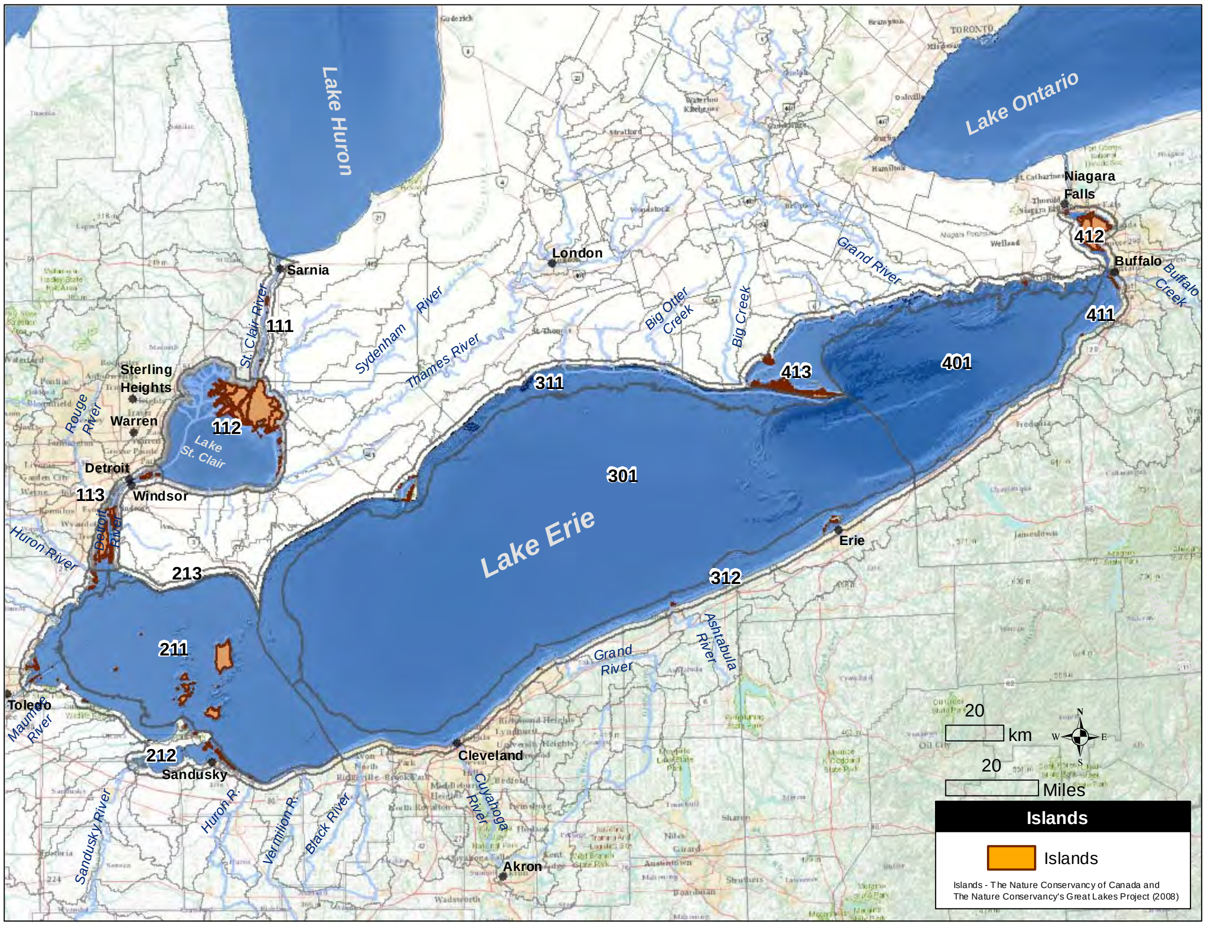

Figure 20: Distribution of Islands in Lake Erie.

Nested targets include: colonial nesting waterbirds, imperiled[8] species (e.g., Lake Erie Watersnake, lakeside daisy (*Tetraneuris herbacea*)), all natural communities that occur on islands (e.g., island forests, alvars, cobble lakeshores), stopover habitat for migrating birds, bats, and insects.

The Great Lakes has the largest system of islands in fresh-water in the world. These islands enrich the biodiversity, culture, and economics of the region. Many of these islands support outstanding examples of plant communities and endemic plant species and are free of some of the pathogens, invasive and overabundant species that occur on the mainland and, in many cases, have a lower magnitude of threat from factors such as inappropriate development and habitat fragmentation. Given that being surrounded by water provides some buffering of high temperatures, islands may act as climatic refugia for some heat-sensitive northern species.

[8] Imperiled species include all G1 – G3 species and declining species such as birds recognized by Partners in Flight. S1-S3 species were not included because of variation in rankings between sub-national jurisdictions.

The islands of Huron-Erie corridor, Lake Erie and Niagara River are very diverse. Lake St. Clair has three large islands that form the core of the St. Clair River delta. These islands are characterized by coastal wetlands and rich lakeplain prairie and savannah. Islands in the Detroit River once included similar communities, but these have been heavily modified for industry and navigation and now just have remnants of coastal wetlands and upland forest. The river islands of the Detroit and Niagara Rivers provide important habitat for breeding, wintering, and migrating colonial nesting waterbirds and waterfowl and have been included in Important Bird Areas in Ontario. There is a concentration of nearshore islands associated with the Lake Erie sandpits, including over 1,000 small islands at Long Point – Turkey Point. These islands are characterized by sand beaches, dunes and coastal wetlands and are very dynamic in number, shape and connections depending on water levels, storm events and coastal processes. The most isolated islands occur in the Western Basin of Lake Erie. These islands are also unique in their origin. While most Great Lakes islands emerged from the lakes and were subsequently colonized by plants and animals that were able to cross from the mainland, the Western Lake Erie Islands were connected to the mainland up until about 4,000 years ago. As the post-glacial water levels of Lake Erie rose, these mainland areas became islands (Karrow and Calkin 1985). As a result, they have an extraordinary richness of species that would not have occurred if they had emerged from Lake Erie, and then been colonized. One subspecies of the Northern Watersnake, the Lake Erie Watersnake, is largely restricted to the islands in the western Lake Erie basin. There are approximately six other globally important species occurring on Western Lake Erie islands. Although most of the larger islands are inhabited and have been significantly altered, patches of forest distinctive to the islands (especially Carolinian forest), some of the southernmost alvars, and large marshes of marshes remain. While the larger islands of the Niagara River have been developed (e.g. Grand Island), Navy Island and most of the smaller island are generally intact.

Islands are significant for both ecological and economic reasons. Islands provide an important ecological benchmark. Interactions between species on islands may continue to drive ecosystem dynamics and provide guidance for management in other places. Many of Lake Erie's islands are biodiversity "hot-spots", and three Lake Erie/ Lake St. Clair islands score in the top 10 for overall biodiversity of Great Lakes islands (Pelee, Walpole, Long Point complex) (Henson et al. 2010). Economically, there are many benefits of maintaining and protecting intact island landscapes. For example, lower densities of deer may result in lower incidence of Lyme disease (which is spreading as the range of deer ticks expands) and thus greater attractiveness of islands to tourists, and land management may be less expensive given the relatively high and persistent costs associated with invasive, pathogen and overabundant native species on mainland areas.

Lake Erie islands are home to many colonies of nesting waterbirds, including Double-crested Cormorants (*Phalacrocorax auritus*), Common Tern (*Sterna hirundo*), Caspian Tern (*Sterna caspia*), Herring Gull , and Ring-billed Gull (*Larus delawarensis*), and the most species-rich collection of herons in the Great Lakes, including several species, such as Little Blue Heron (*Egretta caerulea*) and Snowy Egret (*Egretta thula*) that do not nest on islands in any other Great Lake (Weseloh et al. 1988). Some of the largest concentrations of migratory birds in the Great Lakes region, including landbirds, shorebirds, and waterfowl occur on islands or adjacent nearshore areas (Ewert et al. 2006). Nearshore areas and nearby shoals are important spawning and nursery areas for many fishes and support important recreational fisheries for walleyes and other species.

Islands Goal

By 2030, to ensure that Islands remain as intact and sustainable ecological systems:

- A minimum of 30% of Lake Erie islands and a minimum of 15% of Lake St. Clair/ St. Clair River/ Niagara River islands (by area) are owned and managed for conservation;
- A minimum of 40% of Lake Erie islands are in natural land cover;
- The abundance and richness of colonial nesting waterbirds is maintained within 1990-2010 range of variation;
- All islands are protected by quarantine from known vectors of invasive species;
- Maintain island habitat in an undeveloped condition to support colonial nesting waterbirds, including cormorants, on the islands that have been historically used by nesting colonial nesting waterbirds.
- Maintain and enhance extant native island vegetation communities and species – check indicators

4.7.1. Viability of Lake Erie Islands

The overall viability of Islands was assessed as *Fair*. The assessement was based on land use including: natural cover, density of roads/buildings, shoreline hardening and conservation ownership. Biodiversity measures such as the viability ranks of tracked species and communities documented from islands and information on colonial nesting waterbird use was also incorporated into the analysis. The assessment of viability also drew upon the existing information from the recent basin-wide analysis of Great Lakes islands (Henson et al. 2010).

The isolation, inaccessibility and physical characteristics of many Lake Erie islands has resulted in present-day ecosystem health that is generally higher than the mainland, though the overall viability status of Islands was also assessed as *Fair*. Compared to the mainland, islands tend to have more natural cover and natural communities that have higher EO ranks (both indicators ranked *Good*), but levels of conservation ownership on high priority islands are apparently lower than the mainland as that indicator was ranked *Poor* overall (Appendix E). The main threats to islands are shoreline alterations and invasive species.

The isolation that contributes in many cases to more intact natural systems, and persistence of rare species on islands also suggest that these systems will only very slowly gain more species if current ones are lost due to a changing climate. While some species that are shifting north (or declining) on the mainland may persist longer on some islands due to the climatic buffering from the lake relative to the mainland, some species are still likely to be stressed by changes. Unless these species can successfully move across water or ice, the limited area of islands represents a major constraint to adaptation. In addition, potential changes in lake level, and changes in the dynamics of ice, wind, and currents, have the potential to directly influence the area of islands and coastal disturbance regimes (see Appendix H).

The viability of Islands of the Huron-Erie Corridor is very variable (see Figure 21 and Appendix E for details) and is primarily driven by island size, as larger islands are more likely to have higher concentrations of recreation, industry and agriculture. The islands of the St. Clair Delta are generally in good health. Management of the coastal marshes and lakeplain prairies for wildlife and natural heritage by private clubs, government the Walpole Island First Nations have maintained much of the delta's islands. Many of the other islands in the Huron-Erie Corridor have been heavily impacted by industrial use and navigation. In particular, the islands in the Detroit River have been used for dumping (e.g., Fighting Island), residential development (e.g., Grosse Ile, Bois Blanc) and have been modified by dredging and dumping for navigation (e.g., Grassy, Crystal). Grosse Ile ranks as one of the most threatened islands in Great Lakes based on existing land uses (Henson et al. 2010). Recent successful restoration efforts on Fighting Island and he designation of the Detroit River International Wildlife Refuge in 2001 and complimentary efforts in Ontario through the Western Lake Erie Watersheds Priority Natural Area initiative, has supported the conservation and restoration of these islands.

The health of Islands of the Western Basin varies depending on island size, with larger islands experiencing more intensive use. The larger islands (Pelee, Kelleys, South Bass, Middle Bass) all have a history of agricultural use. This land use has generally been reduced over the last century, and the main agricultural activity on these islands is now viniculture. These larger islands also have permanent residents, high concentrations of second homes and facilities to support recreational boaters. Parks and protected areas have been established on many of these larger islands. Kelleys Island is considered to be one of the 10 most threatened islands in the Great Lakes region and one of the most valuable from a biodiversity perspective in Lake Erie (Henson et al. 2010). Many of the smaller islands in the western are also protected and in good health – including the offshore islands (e.g., Middle, Green) and, to a lesser extent, nearshore islands near Sandusky and Toledo. Several of the offshore island are being managed to control populations of Double-breasted Cormorant to reduce impacts to plant communities and other colonial nesting waterbirds.

The Islands in the Central and Eastern Basin are mostly nearshore systems that are associated with sand spits (Rondeau, Long Point, Presque Isle) and breakwalls. These sand spit features are generally protected and are in provincial, state and federal ownership. These islands have limited development, are characterized by intact natural vegetation and are generally in good health. Grand Island in the Niagara River has been heavily impacted by land uses that are linked to the mainland. Many of the other 36 islands of the Niagara River are in natural cover.

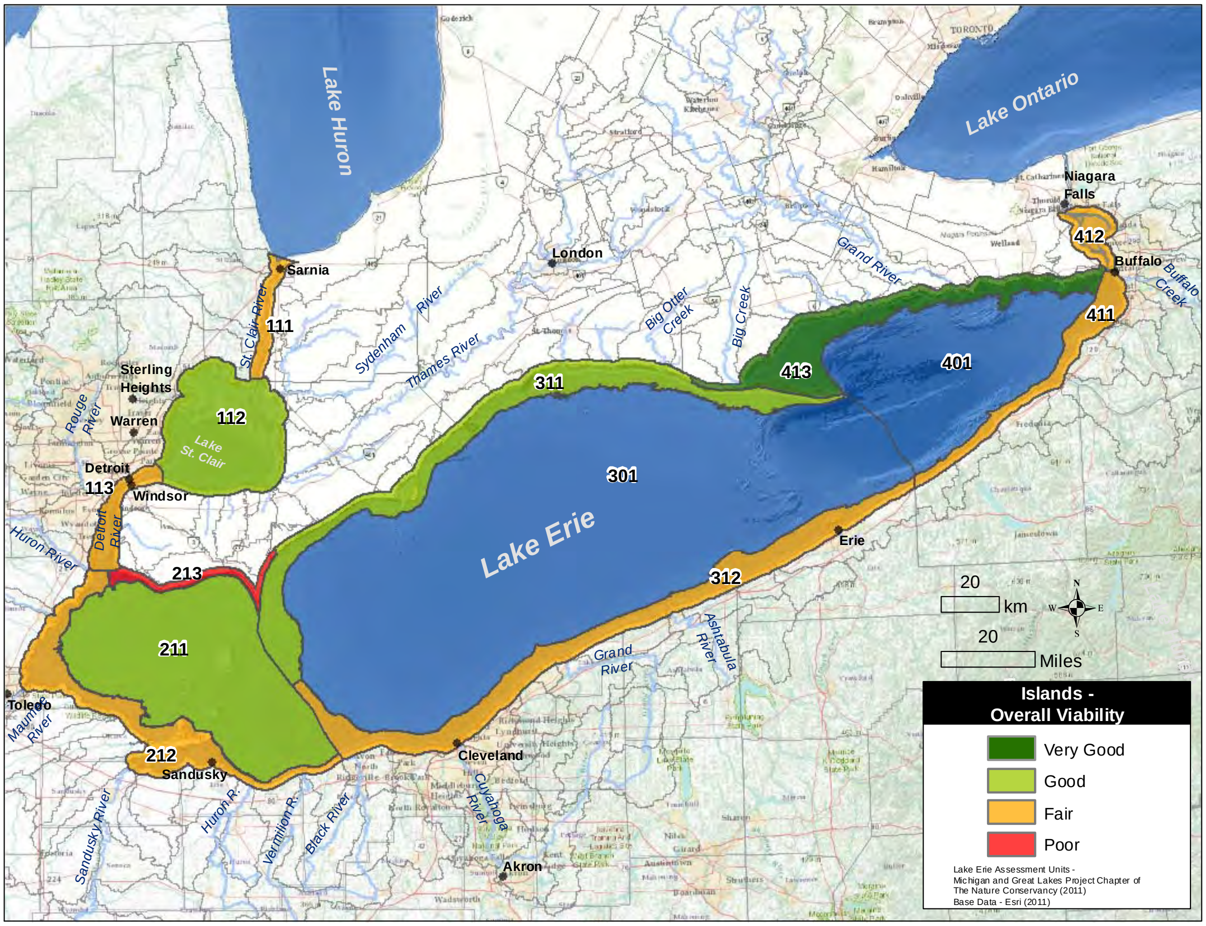

Figure 21: Viability of Islands at the assessment unit level

4.8. Coastal Terrestrial Systems

The Coastal Terrestrial System target 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 22). These areas are inextricably linked to the biodiversity and health of the Nearshore Zone, and contribute to the transfer of biomass and sediments into Lake Erie. In areas where there is shoreline development or other modifications, the health of the Coastal Terrestrial System may be significantly impacted, causing changes to habitats, nutrient cycles, physical processes, and species assemblages (SOLEC 2009, Dodd and Smith 2003).

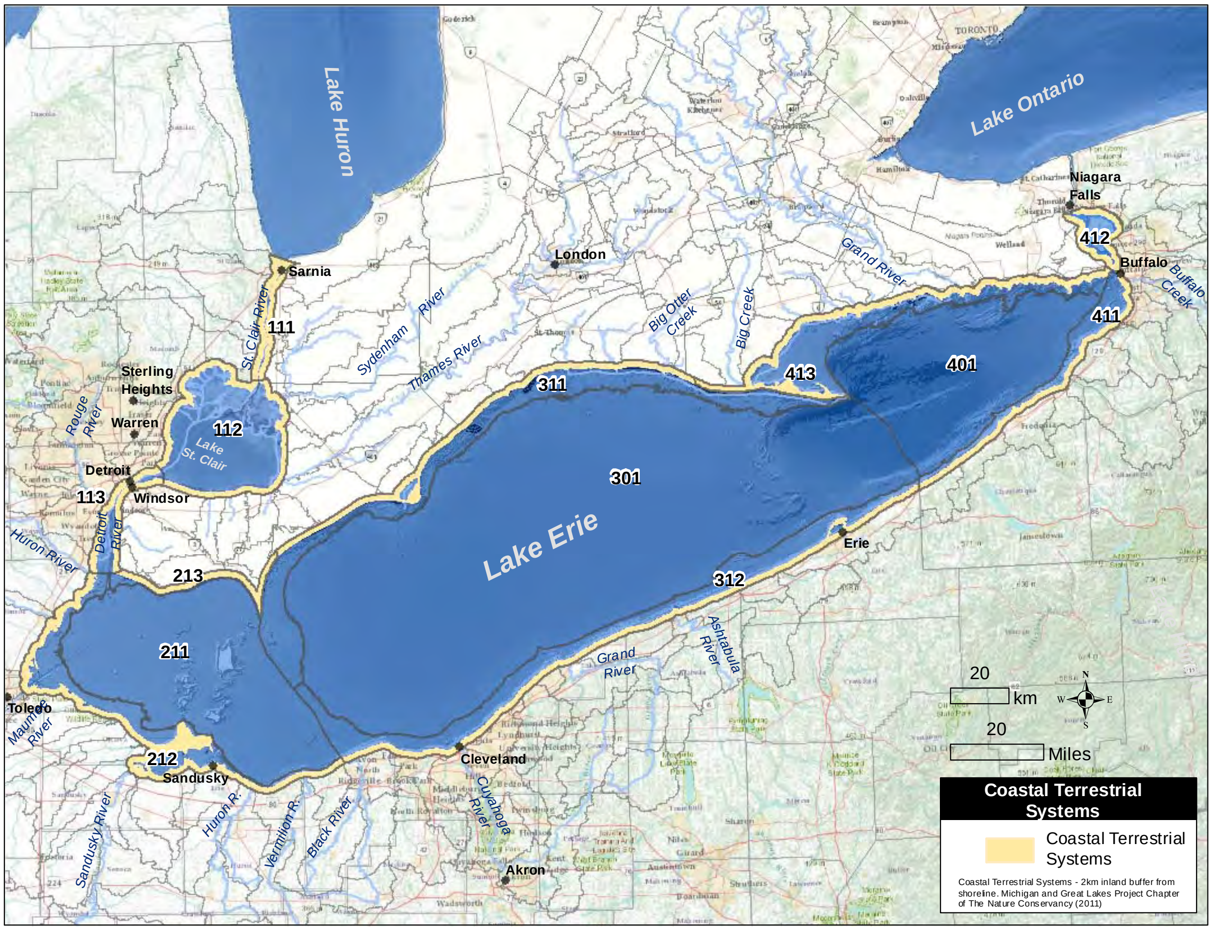

Figure 22: The Coastal Terrestrial System in Lake Erie

This dynamic environment provides critical habitat for migratory birds (SOLEC 2009), and supports numerous endemic and globally rare species and coastal communities. Lake Erie's coastal terrestrial environment is primarily characterized by inland forested and non-forested wetlands, sand beaches, small foredunes, cliffs, and remanant savannas. Great Lakes marshes and other coastal wetland communities are addressed in the Coastal Wetland System target.

Of all the biodiversity targets identified in this project, the Coastal Terrestrial System of Lake Erie contains both the highest number of nested targets and number of occurrences. Along the 1400 km of shoreline, approximately 4,781781 element occurrences representing 822,822 unique natural features are known to occur here (based on 2010 data from the five heritage programs). Coastal Terrestrial System nested targets are restricted to plants, animals and natural communities tracked by each of the five heritage programs located in the Lake Erie Basin. All element occurrences within 2 km of the shoreline were included in the indicator analyses. However, a more discrete list of priority nested targets was created based on their coastal affinity and significance (see section 7 on spatial priorization of conservation targets). A partial list of nested targets is listed below by category (plant, animal, and natural community).

Nested targets include:

Plants: Eastern white-fringed orchid (*Platanthera leucophaea*), Sullivant's milkweed (*Asclepias sullivantii*), Pumpkin ash (*Fraxinus profunda*), Lakeside daisy, Bushy cinquefoil (*Potentilla paradoxa*), and Beach peavine (*Lathyrus littoralis*);
Animals: Eastern fox snake (*Pantherophis gloydi*), Blazing star borer (*Papaipema beeriana*), Elusive clubtail (*Stylurus notatus*), and Duke's skipper (*Euphyes dukesi*);
Natural Communities: Forested wetland, Emergent marsh, Beach-dune systems, Oak savanna communities, alvar/bedrock communities (including cliffs) and Upland forest.

The Coastal Terrestrial System is highly imperiled in Lake Erie due to continued habitat loss from development, fragmentation, separation from the lake by hardened shoreline structures, and the spread of invasive species. The majority of the remaining Coastal Terrestrial System is highly fragmented and primarily consists of small, isolated natural communities.

Coastal Terrestrial Goal

The desired future condition for the Coastal Terrestrial System was based on input from coastal experts most familiar with the Lake Erie coastal environment. By 2030, to assure that Coastal Terrestrial System is of high quality and of sufficient extent to provide habitat for native plant and animal species:

- At least 40% of the Coastal Terrestrial System will be in natural land cover;
- Viable populations of nested targets are adequately represented across the lake
- At least 5% of the Coastal Terrestrial System will be in good to excellent condition;
- The average artificial shoreline hardening index will be below 20%;
- All significant biodiversity areas in the Coastal Terrestrial System are unaffected by shoreline alterations

4.8.1. Viability of Coastal Terrestrial Systems

The viability of the Coastal Terrestrial System was based on several criteria or indicators. Some are general in nature and relatively easy to monitor over time with publicly available data, such as land cover, road density, and housing density. Others indicators more specifically address key stressors, such as the amount of shoreline hardening, or bedload traps and groins, and data sources typically don't have regular data updates. Additional indicators such as rare species and high quality natural communities are excellent indicators of the health of specific sites. Although data are incomplete and highly variable, these sources provide the best data currently available at the site scale. Ideally each stretch of shoreline would be assigned a certain level of health or viability using an objective set of criteria, similar to how heritage programs assess natural communities. Currently, the status of indicators for this target varies considerably across these assessment units (see Figure 23 and Appendix E for details).

The overall condition of the Coastal Terrestrial System was assessed as *Fair* due to the high amount of road/building density, hardened shoreline, and both urban and agricultural land use. Road and building density are very high throughout the basin with the exception of the Central Basin reporting unit. Shoreline hardening is a problem all along the Lake Erie coastline, particularly along the two connecting channels. Plant and animal element occurrences are generally *Fair* to *Poor* condition, while natural communities typically rank as *Good* condition.

Viability of the Coastal Terrestrial System in the Huron to Erie Corridor is estimated to be in *Fair* condition. This is by far the most heavily urbanized and populated unit in Lake Erie. None of the indicators in any of the three assessment units were given a ranking higher than *Fair*. Road density is extremely high throughout, percent natural lands is as low as 8% in the Detroit river assessment unit, and artificial shoreline hardening index is as high as 72% along the St. Clair River. Although very few occurrences of terrestrial natural communities remain in this unit, several priority natural communities, lakeplain prairie, oak openings, and wet-mesic flatwoods, are indicative of this region's circa 1800 vegetation, and can still be found here in isolated pockets. Despite the relatively *Poor* condition of the Coastal Terrestrial System, there are several priority animal and plant species: eastern fox snake, blazing star borer, elusive clubtail, Sullivant's milkweed, eastern white-fringed orchid, and pumpkin ash.

Viability of the Coastal Terrestrial System in the Western Basin is estimated to be in *Fair* condition. Similar to the Huron - Erie Corridor reporting unit, the remaining natural lands of the Western Basin are primarily Coastal Wetlands. The Terrestrial Coastal System of the Western Basin is dominated by agriculture in Ontario, and urbanization on the United States side of the lake. Aside from *Good* to *Very Good* ratings for natural community element occurrences, all indicator ratings ranged from *Poor* to *Fair* condition. The only priority natural communities remaining in this unit are several types of beach-dune communities. Only two animal species, eastern fox snake and Duke's skipper, are considered to be priorities. Priority plant species are eastern prairie-fringed orchid, and lakeside daisy.

Similar to the Western Basin, the viability of the Coastal Terrestrial System in the Central Basin was also rated as *Fair*. Indicator scores ranged from *Poor* to *Very Good*; however the majority of indicators were rated as *Fair*. The Canadian coastal zone along the northern shore of the Central Basin is dominated by agricultural lands, while a large portion of the U.S. coastal zone is dominated by the Cleveland metropolitan area. Priority natural communities include several oak savanna and beach-dune community types. There are only two globally imperiled plant species known to occur here; each with only one extant occurrence on the Ontario side of the Basin. As a result, no priority species were identified for this unit.

Like the Western and Central Basins, the viability of the Coastal Terrestrial System in the Eastern Basin is estimated to be in *Fair* condition. This reporting unit includes the coastal zone of the deep Eastern Basin as well as the Upper Niagara River corridor. Although the Eastern Basin contains some of the highest percentages of natural lands in the Lake Erie Basin, it also has some of the highest road densities, and the Niagara River has the highest percentage of artificial shoreline hardening (77%) in Lake Erie. Priority natural communities are dune communities and oak savanna. In addition, due to the high amount of alteration and fragmentation along the shoreline, very few globally imperiled plants and animals are found in this unit. Of the eight globally imperiled species found here, there are only two occurrences with an A-D rank and two occurrences with an E rank (extant). Since no globally imperiled species have more than one element occurrence with an A-E rank, no priority species were identified for the Eastern Basin.

The majority of indicators for assessing the viability of the Coastal Terrestrial System are based on relatively old or incomplete data. For example, the data on shoreline types and hardening is from the late 1970's for the state of Michigan, and from the late 1980's for remainder of the basin. Related to this, is a strong need for a Great Lakes shoreline classification system and a systematic survey of the entire Lake Erie basin shoreline to compile information on shoreline type, condition, and landscape context. Additionally, the element occurrence data from the heritage programs is highly variable in terms of accuracy, comprehensiveness, and age, with the vast majority of occurrences greater than 20 years old. The majority of animal occurrences have a viability rank of (E) for extant; meaning there is insufficient data to assign a more meaningful rank of A-D. Likewise, it appears that the groins and piers data are inaccurate (numbers too low) for numerous assessment units along the Canadian shoreline.

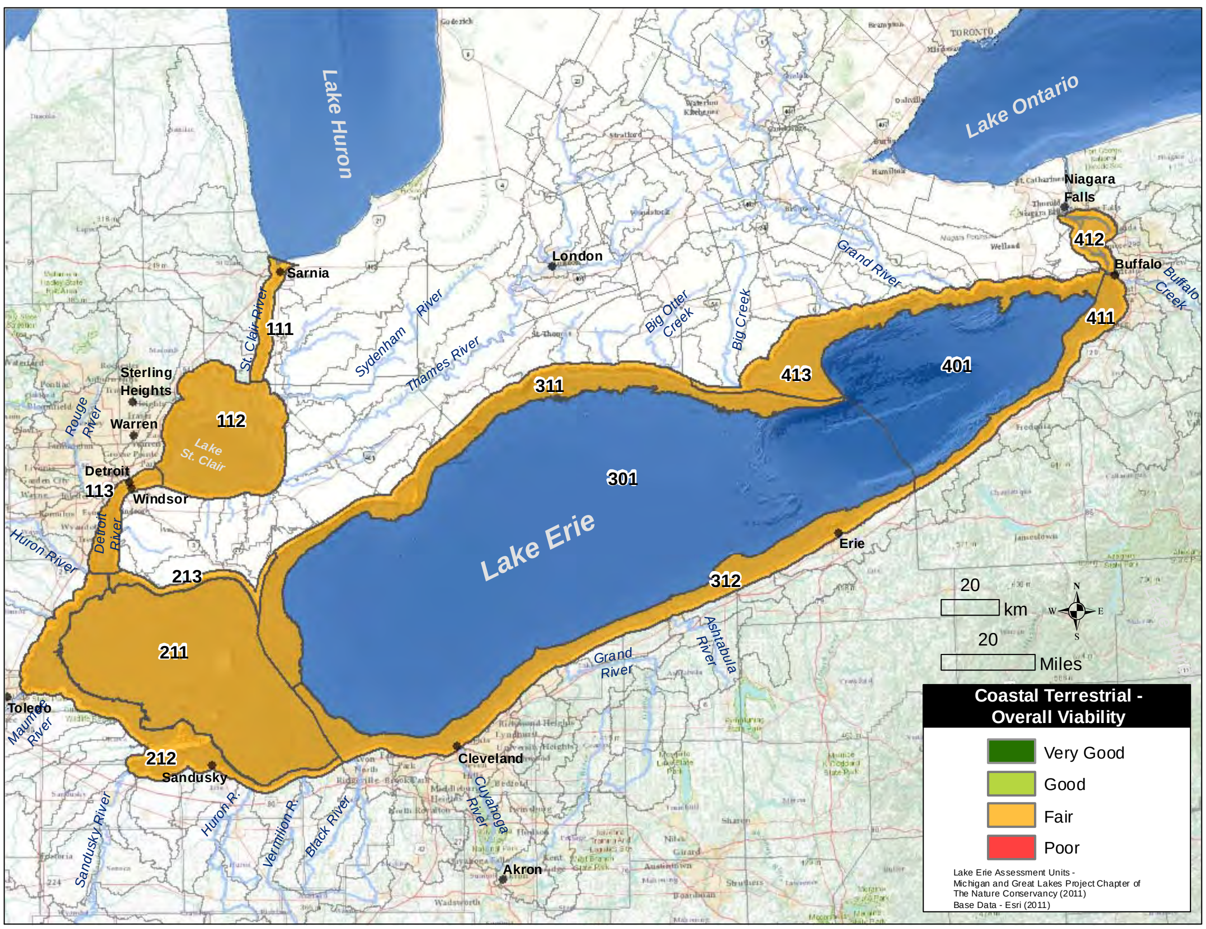

Figure 23: Viability of Coastal Terrestrial at the assessment unit level

Climate change is likely to increase the regional variation described above across the various reporting units. For example, the areas that are most fragmented and have already lost the most natural habitats are likely to lose more of their native species and natural communities than other areas with a higher proportion of natural land cover. Isolated systems surrounded by human-dominated land uses may not be able to persist in the same location as conditions change. Where variation and connectivity persists, species and functional systems are also more likely to remain more viable in the future (see Appendix H).

4.9. Aerial Migrants

We defined Aerial Migrants as birds (landbirds, waterfowl, shorebirds, waterbirds) that use open waters of Lake Erie and adjacent shorelines, including connecting waters, during spring and fall migration. Migratory bats and insects (e.g. butterflies and dragonflies) are excluded from this analysis because there are too few data to describe distributional patterns and factors associated with their viability during migration anywhere in the Great Lakes region, including Lake Erie. However, these species are nested in this target with the assumption that many of the habitat characteristics that support stopover habitat for landbirds also supports these species groups.

Nested targets include: all types of migrating birds.

This diverse set of bird species occupies a wide range of habitats where they refuel and rest at stopover sites (Figure 24). The Great Lakes serve as major migratory corridors for waterfowl and waterbirds (loons, grebes, herons, rails, cranes, gulls and terns) as well as providing important stopover habitat for landbirds, including many species of raptors (Figure 25). The highest concentrations of landbirds (including songbirds and raptors) migrants tend to be within 2 km of the shoreline, especially during spring migration, due to relatively abundant food supplies and “fall-out”, areas where migrants concentrate on the nearest land after overwater flights. Waterfowl are typically found in nearshore waters < 6 m deep although some species can be found in much deeper waters, most notably Long-tailed Duck. Like landbirds, shorebirds are most common in suitable habitats (e.g., beaches, flooded fields, wetlands) relatively close to the Great Lakes. The distribution and abundance of Aerial Migrants is dependent on both the amount and, and perhaps secondarily, on the quality of Coastal Terrestrial Systems and Nearshore Zone.

Lake Erie, and the shoreline, provides globally or continentally important stopover sites for waterfowl, shorebirds, landbirds and waterbirds at many locations, including Point Pelee, Pelee Island, and Long Point, Ontario; Pointe Mouillee and Erie Marsh, Michigan; the islands and southwest shoreline of Lake Erie in Ohio; the Niagara River, New York and Ontario and Presque Isle, Pennsylvania[9]. Particularly high numbers of Tundra Swans (*Cygnus columbianus*), Canvasbacks (*Aythya valisineria*), Red-breasted

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[9] (http://iba.audubon.prg/iba/prioritySiteIndex.do?priority=Global ; http://www.ibacanada/explore.jsp?lang=en).

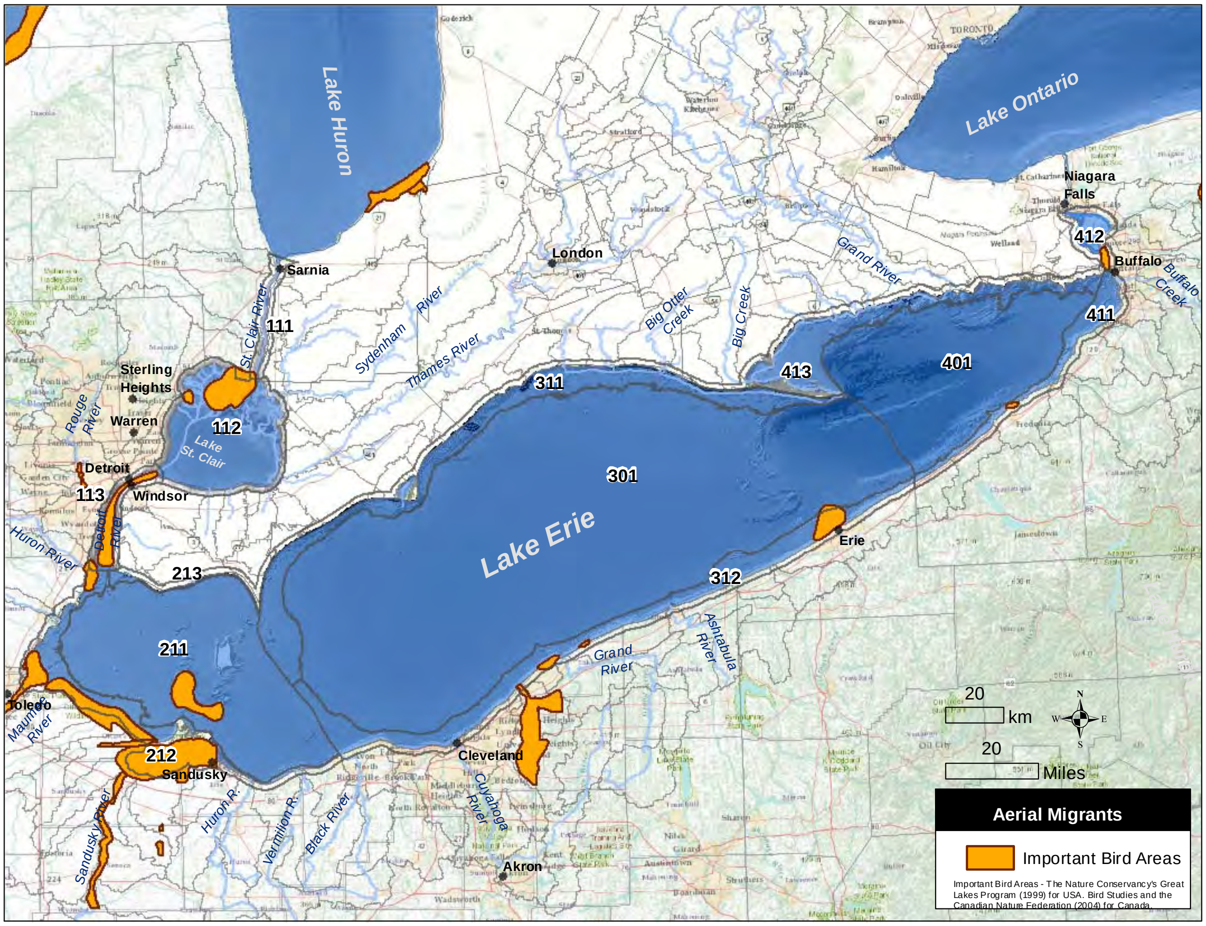

Figure 24: Important Bird Areas in Lake Erie.

Mergansers (*Mergus serrator*), and songbirds, occur near the shoreline of Lake Erie. Identifying, protecting, and managing important stopover sites in the Great Lakes region may contribute disproportionately to maintaining populations of these, and other, migrant species. Many of these sites, including associated threats and strategies, have been identified by Important Bird Area programs in Michigan, New York, Ohio, Ontario, and Pennsylvania.

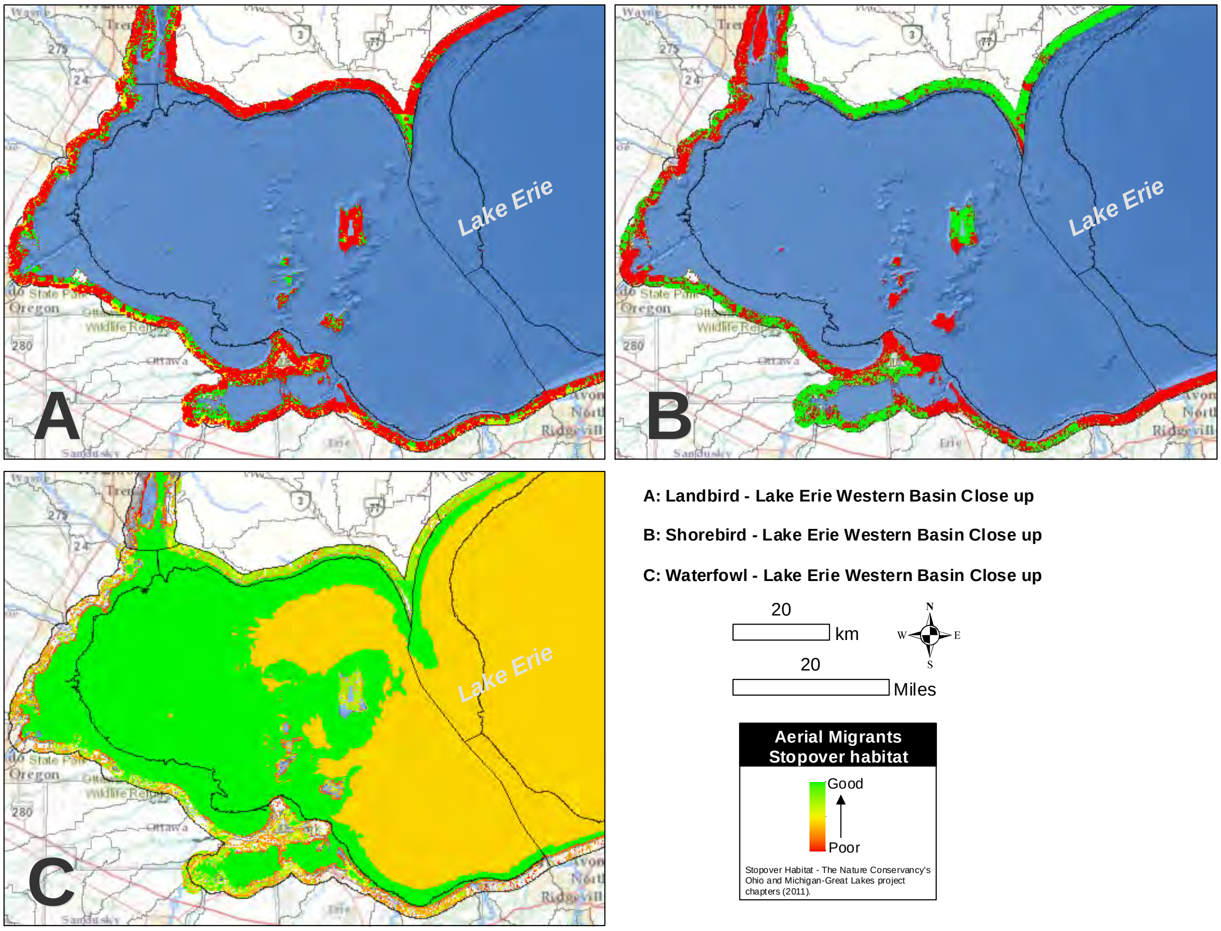

Figure 25: Example of habitat stopover sites in Lake Erie for three bird groups (Data from Ewert et al. 2012).

Stopover habitats have been highly altered by anthropogenic activities. Habitat loss, and the associated consequences such as fragmentation and increased presence of invasive species, have impacted the health of many stopover sites. Other factors that may have also contributed to loss or degradation of stopover habitat include pollutants and infrastructure, including wind energy. These threats primarily affect Aerial Migrants through loss of food resources and secondarily by direct mortality from disease (e.g., botulism) or striking structures. Feral cats may also be a source of mortality.

Aerial Migrants Goal

The desired future condition for the Aerial Migrants was based on input from experts and literature review.

By 2030, so that Lake Erie remains a globally significant stopover area for migrating birds:

- At least 30% of the 2 km coastal area comprises high quality stopover habitat for migrating landbirds;[10]
- At least 10% (very rough guess) of the coastal area comprises high quality stopover habitat for migrating shorebirds;
- At least 50% (very rough guess) of the 2 km coastal area, including coastal wetlands, comprises high quality stopover habitat for migrating waterfowl;
- At least 80% of the 2 km coastal area that is high quality stopover habitat for all bird groups is in conservation ownership or management.[11]

4.9.1. Viability of Aerial Migrants

Migratory birds have been sampled at the continental scale more than most taxa, but it is still largely unknown what phases of the life cycle drive population trends and how this varies spatially and temporally, especially during migration (for most species). Consequently, given our current knowledge and availability of spatial data, we can best assess viability for Aerial Migrants by the amount and distribution of habitat. This is best done by assessing trends in the distribution and amount of suitable habitat from the most current land cover data layers. We assessed viability of migrants at stopover sites indirectly by assuming that attributes of sites that support large number of migrants are usually associated with sites with increased survival and/or relatively high rates of mass gain, given exceptions such as emergency landfall areas as described by Mehlman et al. (2005).

We reviewed the literature and consulted with experts and concluded that migrant viability is enhanced based on the following conditions:

Landbirds: 1) landscapes are relatively intact and 2) stopover sites are relatively close to water, either the Great Lakes or inland non-Great Lakes waters.

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[10] Based on literature review indicating that where approximately 40% of landscape is in natural cover there is little density compensation of land birds in habitat patches. Not all this habitat has to be high quality so this accounts for the fact that a mix of both high quality and some low quality habitat may be sufficient for land bird passage during migration.

[11] Goal based on protecting as much as possible and knowing that 100% is not feasible. This goal should be stepped down locally as it will not be possible to achieve this goal along 2 km shoreline stretches in Cleveland, for example.

Shorebirds: 1) stopover sites are relatively close to the Great Lakes, and 2) when wetlands are relatively large, clustered, cover a relatively large proportion of the landscape, and when the surrounding landscape is undeveloped and offers few perching sites for avian predators and are distant from anthropogenic disturbance.

Waterfowl: 1) wetlands are relatively large, clustered, and 2) when the surrounding landscape is undeveloped and relatively unfavorable for predators and distant from anthropogenic disturbance and, in open waters, in water depths ≤ 9m.

The criteria for establishing viability will require more testing as the viability assessment is based on relatively few studies from sites within and outside the Great Lakes region. Based on previous and ongoing mapping of stopover habitat following these conclusions, we have developed a set of KEAs and indicators (see Appendix E for details).

The overall viability for Lake Erie Aerial Migrants is *Good*. Viability for Aerial Migrants is generally better for landbirds than shorebirds and waterfowl, a likely consequence of the relatively local distribution of suitable habitat, primarily wetlands, for shorebirds and waterfowl. Relatively few wetlands are found along the St. Clair, Detroit and Niagara Rivers, where there is also much development, so these areas rank lower than most other parts of Lake Erie, except for shorelines in the Cleveland area, for shorebirds and waterfowl. Some of these areas, especially along the Niagara River, may never have been good habitat for migrating shorebirds (Figure 26). Habitat appears to be most limited for landbirds along the south shore of Lake Erie in the Central Basin where development and agriculture have resulted in habitat loss. Important information gaps include 1) describing the relative importance of habitat configuration relative to Lake Erie for landbirds and 2) describing the amount and configuration of suitable habitat needed to support shorebird and waterfowl migrants in the region[12].

While our goals for Aerial Migrants focus on measuring habitat availability, changes in climate may also influence how well systems in the Lake Erie region support migrating birds. A key factor influencing habitat value is the availability of food (i.e., insects, fruit), and both the abundance and timing of resources are important. While birds as a group are highly mobile and often considered less vulnerable than other groups to impacts of climate change because they have the potential to move to habitats with suitable climates, species that migrate are dependent on the timing (or phenology) of a suite of other species (e.g., aquatic and terrestrial insect emergence, plants). This dependence highlights a potential source of risk, yet given our poor understanding of the migratory process, the patterns of future climate change, and our limited understanding of how key prey will respond to change, it is a risk we are not yet able to consider in this work.

[12] As of this writing, stopover habitat mapping is underway through a parallel project funded by the U.S. Fish and Wildlife Service Upper Midwest/Great Lakes Landscape Conservation Cooperative (LCC).

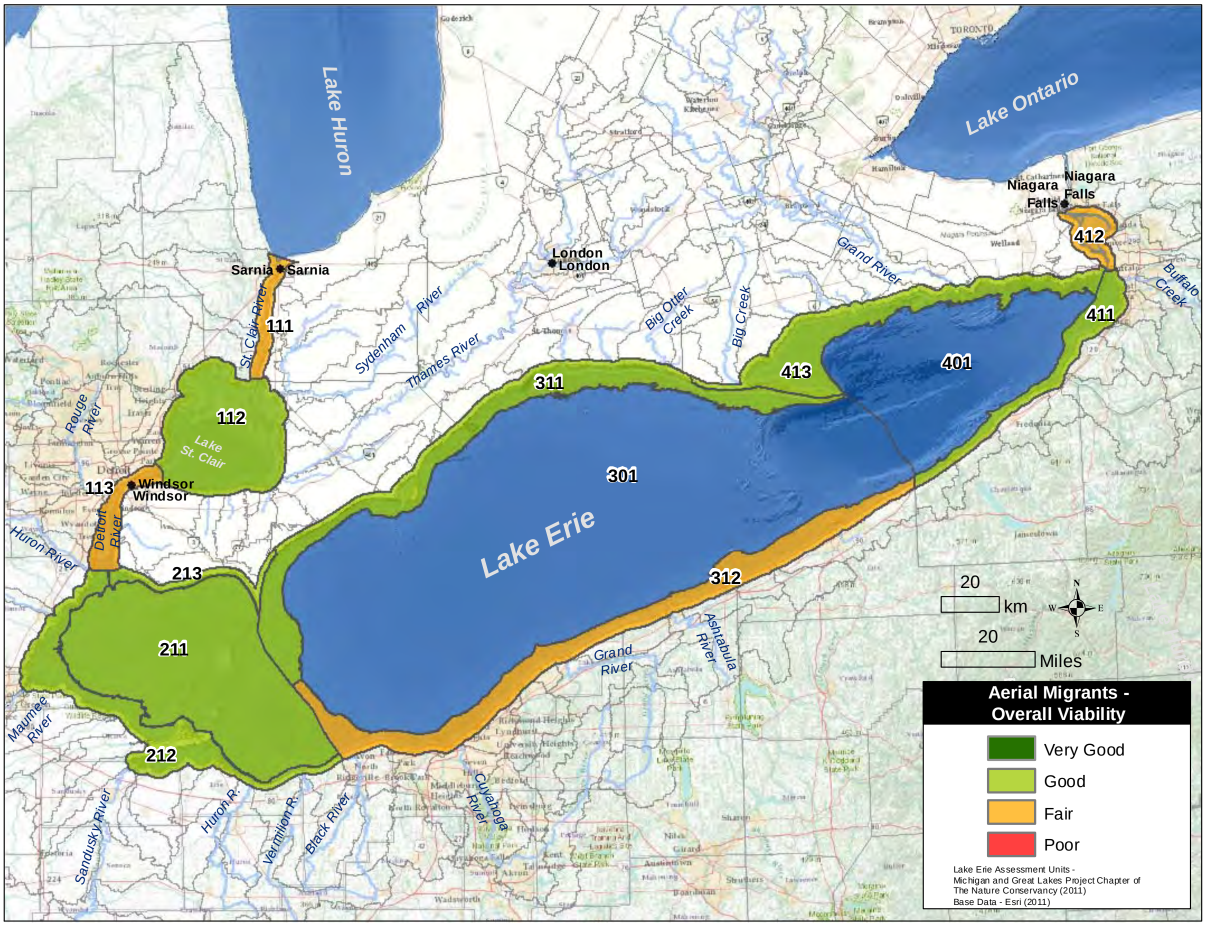

Figure 26: Viability of Aerial Migrants at the assessment unit level.

4.10. Lakewide viability assessment

Lakewide, across all targets, the viability of Lake Erie is considered *Fair* (Table 1). This rating is defined as being "*outside its acceptable range of variation and requires human intervention, and if unchecked, the target will be vulnerable to serious degradation*." (For more information on indicator ratings see Box 1) Since seven of eight targets were rated as *Fair* (Table 1), restorative efforts need to occur broadly across these targets, while maintaining the current *Good* status for Aerial Migrants.

With a closer look at the status of indicators lakewide across targets (Figure 27), it is clear that the majority of indicators fall within the *Fair* category. However, it is encouraging that the proportion of indicators that are rated as *Good* is higher than the proportion rated as *Poor*. Still, given the preponderance of indicators across all targets are rated as *Fair* or *Poor*, substantial restorative work will be necessary to move Lake Erie from *Fair* into an overall status of *Good*. While seven different targets received a *Fair* rating (Table 1), the specific status of indicators within those targets is highly variable. For example, the Offshore had more indicators rated as *Good* than *Fair* or *Poor,* while indicators for

Migratory Fish, Aerial Migrants, Nearshore, Islands, and Coastal Wetlands were dominated by *Fair* ratings (Figure 28). Coastal Terrestrial had more indicators rated as *Poor* indicating that substantial intervention is required.

Table 1: Lakewide viability assessment summary

Target	Landscape Context	Condition	Size	Overall
Nearshore Zone	Fair	Fair	*Not applicable*	**Fair**
Aerial Migrants	Good	*Not applicable*	*Not applicable*	**Good**
Coastal Terrestrial Systems	Poor	Fair	*Not applicable*	**Fair**
Coastal Wetlands	Fair	Fair	Good	**Fair**
Connecting Channels	Good	Fair	Very Good	**Fair**
Islands	Poor	Fair	*Not applicable*	**Fair**
Native Migratory Fish	Fair	*Not applicable*	Fair	**Fair**
Open Water Benthic and Pelagic Ecosystem	Fair	Fair	*Not applicable*	**Fair**
Overall Biodiversity Health	**Fair**	**Fair**	**Fair**	**Fair**

This tendency of having a *Fair* status when the indicators are aggregated to assess the KEA, target or overall status is the result of the aggregation rules used by the CAP process viability analysis. The aggregation process depends on an average and having many indicators with a lot of variability in their ranking status tends to result in the average falling in the mid-point of the ratings. This is exacerbated by the fact that the intervals used to define each rating are not linear, but tend to be wider for the *Fair* ratings (see definitions in Box 3).

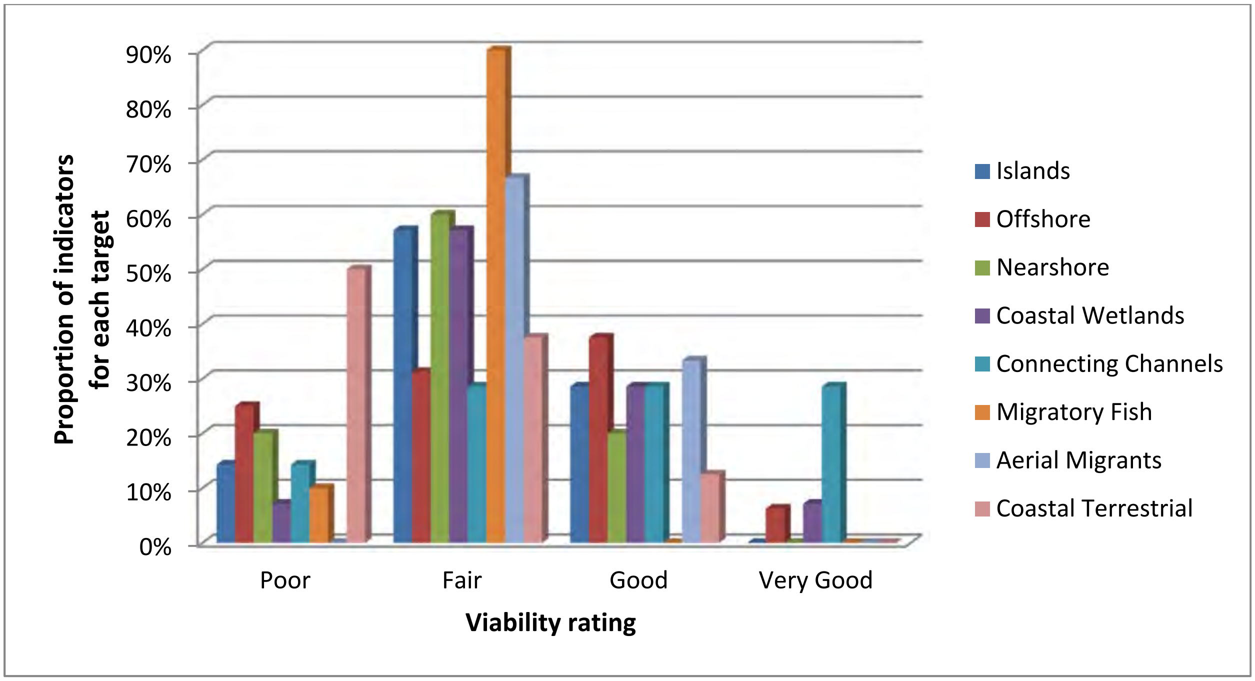

Figure 27. Proportion of indicators for each conservation target that fall within each of the four rating categories (*Poor*, *Fair*, *Good*, or *Very Good*) across Lake Erie. This demonstrates the general status of Lake Erie across all conservation targets.

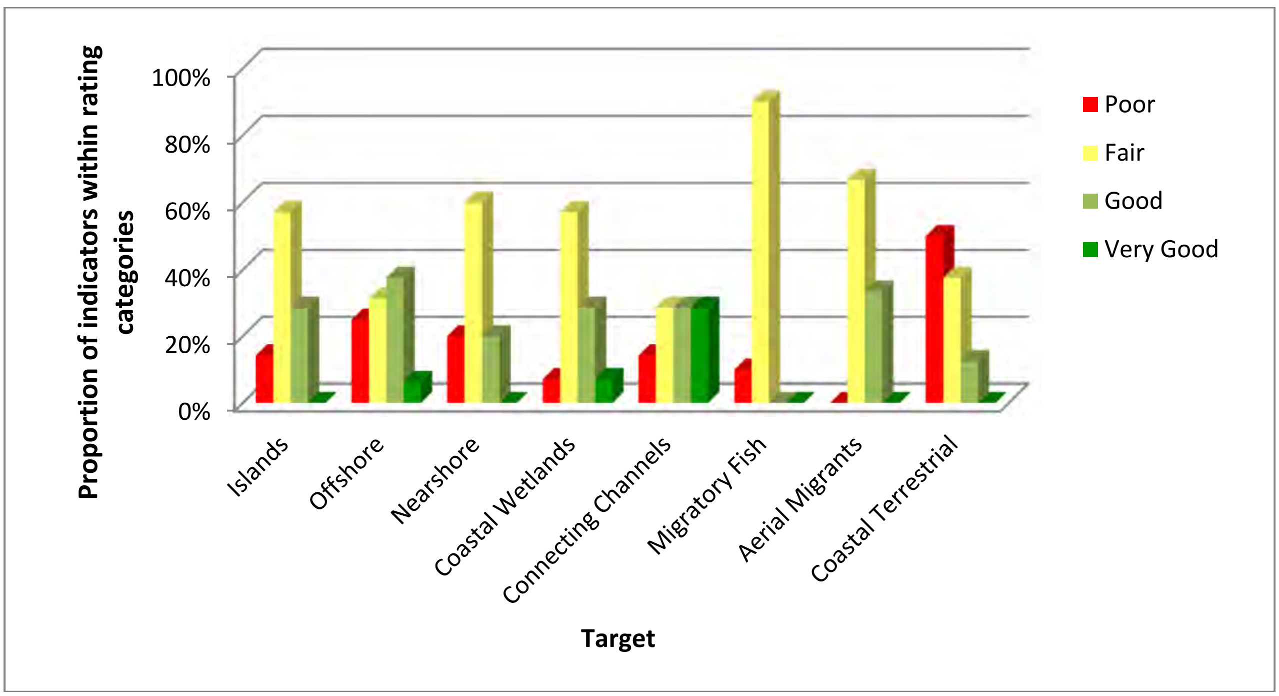

Figure 28. Proportion of indicators for each rating category (*Poor*, *Fair*, *Good*, or *Very Good)* for each target across Lake Erie. This demonstrates how the general status of Lake Erie across all conservation indicators varies among targets.

5. THREATS TO BIODIVERSITY

The waters and basin of Lake Erie are the most heavily impacted in the Great Lakes. The basin is dominated by agricultural and urban land uses, and supports over 12 million people. While the lake can never be returned to pristine conditions, there are several threats that can be effectively mitigated to protect and restore biodiversity. In this chapter we explain how threats to biodiversity targets were identified and ranked throughout the lake and we describe the most critical threats to Lake Erie biodiversity conservation targets. Threat ranks for each reporting unit are included in Appendix G.

5.1. Threat assessment methods: Survey of Lake Erie experts

To assess threats, the Core Team compiled a list of threats from the Lake Ontario and Huron Biodiversity Conservation Strategies, relevant regional plans, Great Lakes Environmental Assessment and Mapping project and other initiatives and reports including the Lake Erie LaMP. The Steering Committee provided additional suggestions to complete the initial list. For consistency purposes we followed a published taxonomy of threats (Salafsky et al. 2008). The team then developed online surveys, one for each of the four Lake Erie reporting units[13]. For each survey, we invited roughly 275 experts (including agency staff, academics, private consultants, organization scientists, see Appendix B) to rate the Scope, Severity, and Irreversibility of each threat to each target for each reporting unit (see Box 4) [14],and also to document their level of confidence with each rating (using the categories of *Very High*, *High*, *Medium*, and *Low*). Experts were also invited to identify and rank threats that weren't included in the list.

In order to improve the accuracy of the information provided through the surveys, an expert-elicitation approach was used to select and to combine expert threat ratings. After the surveys were closed, we compiled the responses and selected them based on the level of confidence of each expert. In order to elicit and combine judgments from participants, we evaluated the expertise level of each survey participant according to their degree of expertise with the targets and the threats. The Core Team identified participants with known experience and expertise on particular threats or targets. We also compiled a list of publications, both peer-reviewed and "gray literature", for all participants, noting publications that were relevant to either a particular threat or target. Participants who were identified through one or both of these processes were tagged as "super-experts" and their responses were given twice the weight of other experts. Expert elicitation is a process that enhances the accuracy and information content of expert judgment and at the same time allows the project team to adequately capture the uncertainty inherent to expert knowledge (Burgman et al. 2011, Martin et al. 2012).

Finally, we averaged the weighted and unweighted values for Scope, Severity, and Irreversibility for each **threat-to-target relationship** in each reporting unit, and entered these average values into *Miradi* software. *Miradi* calculates threat ratings using a rule-based system that combines Scope, Severity, and

[13] Using SurveyMonkey a provider of web-based surveys.
[14] For details on the process refer to the overview of the Conservation Action Process.

Irreversibility criteria, produces an overall threat-to-target rank and calculates ratings for threats across all targets and overall threat ratings for each target. Threats to biodiversity were then assessed at the reporting unit level and aggregated lakewide.

5.2. Critical threats to Lake Erie biodiversity

Of the 18 threats that were included in the survey (Box 7), ten were ranked either *High* or *Very High* in at least one reporting unit (Table 2). Aquatic invasive species achieved the top overall rank based on a *Very High* rank in the Huron – Erie Corridor, and *High* ranks in the other three reporting units (see Appendix G for details). Climate change (habitat shifting and alteration), terrestrial invasive species, and agricultural non-point source pollution were all ranked as *High* threats in every basin, and two other threats (housing/urban development and shoreline alterations) were ranked *High* in three of the four basins. The other *High* -ranked threats include contaminated sediments and pollutants from industrial and urban sources. Note that in addition to contributing to the threat of "Habitat shifting and alteration", climate change acts as a "threat multiplier" in some cases (e.g. increases in storm intensities tend to increase the magnitude of the threat of "Pollution: Agriculture sources"). Our goal was to consider these interactions within the ranking of the primary threat, however given the timeframe of the threat assessment ranking (current to +10 years), and the gradual yet pervasive nature of the climate change threat, integration with the threat ranking step represents a definite challenge. While it is likely that not all participants considered climate change interactions with these other stressors in their assessments of threats ranking, the need to address, and think ahead about climate change was emphasized in the strategy development steps.

Box 7: Threats included in the survey

- Climate Change: Habitat Shifting & Alteration
- Contaminated Sediments
- Dams & Other Barriers
- Diking of Wetlands
- Housing & Urban Development
- Incompatible Fisheries Management
- Invasive Non-Native Aquatic Species
- Invasive Non-Native Terrestrial Species
- Mining & Quarrying
- Navigation & Recreational Dredging & Blasting
- Non-renewable Energy
- Pollution: Agriculture and Forestry Sources (includes nutrients)
- Pollution: Airborne Sources
- Pollution: Industrial Sources
- Pollution: Urban and Household Sources
- Recreational Activities
- Renewable Energy
- Shoreline Alterations

The threats that were identified through this process are mostly in line with other studies, such as the Lake Erie LaMP (U.S. EPA 2008). The LaMP identifies many of these threats as causes of beneficial use impairments, though there is no ranking of the relative significance of the causes. The recent focus of the LaMP, the LaMP Public Forum, and many agencies and organizations on nutrients (cf. the Status of Nutrients report (U.S. EPA 2009b) and recent Lake Erie Binational Nutrient Management Strategy (Lake Erie LaMP 2011)) would suggest that agricultural non-point source pollutants, especially phosphorus, might have come out as the top-ranked threat, at least in the Western Basin. A possible explanation for the result is that the threat was characterized as both agricultural and forest sources of pollutants, possibly resulting in some confusion or diluting the ratings of impact. Also, dams and barriers did not arise as a *High* threat, possibly due to the distinction in the assessment between dams and wetland dikes. The Steering Committee recommended that dams and barriers be combined with diking of wetlands, due to the similarity of impact on accessibility of spawning habitat, and treated as a priority threat.

Table 2: Table of threats that scored *High* or *Very High* in at least one reporting unit, with highest overall ranking at the top (roughly)*.

	Huron – Erie Corridor	Western Basin	Central Basin	Eastern Basin
Invasive aquatics	Very High	High	High	High
Climate: habitat shifting/ alteration	High	High	High	High
Invasive terrestrial	High	High	High	High
Pollution: Agriculture	High	High	High	High
Housing/urban development	High	High	Medium	High
Shoreline Alterations	High	High	Medium	High
Contaminated sediments	Medium	Medium	Medium	High
Pollution: industrial	High	Medium	Medium	Medium
Pollution: Urban/household	Medium	Medium	Medium	High

*Table only includes threats that were identified and ranked by more than one individual.

For efficiency, the Core Team and the Steering Committee combined some threats in those cases where the contributing factors and likely strategies were considered similar or complementary (Box 8).

Box 8: Aggregated Critical Threats

1. Invasive species
2. Non-point source pollution
    - Agricultural non-point pollution
    - Urban non-point source pollution
3. Housing and urban development, coupled with shoreline alterations
4. Dams and barriers
5. Climate change

Climate change was deemed to be a cross-cutting threat with multiple drivers and interactions, and thus, as described in the following chapter, it was considered across all strategies. Given the rapid advances in research on climate change in the Great Lakes, the fact that many targets may be vulnerable to several types of climate change impacts, and the potential for these vulnerabilities to influence both what is possible in the future (i.e. our goals), and our strategy effectiveness, we include a broad description of regional climate change and its impacts on Great Lakes biodiversity in Appendix H.

5.2.1. Why are invasive species a critical threat?

Invasive species, both aquatic and terrestrial, have been identified as a *High* to *Very High* threat in the three basins of Lake Erie and the Huron-Erie corridor (Table 3). All targets, Islands, Native Migratory Fish, Aerial Migrants, Offshore Zone, Nearshore Zone, Coastal Terrestrial Systems and Coastal Wetlands, are threatened by invasive species (Table 4).

Table 3: Overall threat ranks for invasive species in reporting units of Lake Erie.

	Huron – Erie Corridor	Western Basin	Central Basin	Eastern Basin
Aquatic Invasive Species	Very High	High	High	High
Terrestrial Invasive Species	High	High	High	High

Table 4: Ratings of threat to each target for invasive species in reporting units of Lake Erie.

Reporting Units	Islands	Native Migratory Fish	Aerial Migrants	Connecting Channels	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
Aquatic Invasive Species								
HEC		Very High	Medium	Very High		High	Medium	High
W Basin		High	High			High	High	High
C Basin		High	Medium		High	High	High	High
E Basin		High	Medium	High	High	Medium	High	High
Terrestrial Invasive Species								
HEC	Medium	Medium	Medium	Medium		Medium	High	Medium
W Basin	Medium	Medium	High			Medium	High	High
C Basin	Medium	Medium	Medium		Low	Medium	High	High
E Basin	High	Medium	High	High	Medium	Medium	High	High

Aquatic and terrestrial invasive species are critical threats for similar reasons. They can become dominant in communities and ecosystems and outcompete native flora and fauna in the absence of predators, parasites and pathogens which results in loss of native species, community composition and function, nutrient dynamics, and environmental quality. Aspects of climate change, such as increases in water temperatures, and increases in winter minimum temperatures on land (i.e., reductions in winter severity) can facilitate the establishment of invasive species that have not been successful in this region in the past. Invasive species can spread rapidly and pose difficult management questions.

Although the rate of new introductions has slowed, aquatic invasive species are particularly difficult to control because they disperse so readily; their ability to invade new habitats has led to rapid range expansions. Over 70 aquatic invasive species have been identified in Lake Erie including sea lamprey (*Petromyzon marinus*), zebra and quagga mussels and round goby. Lake trout and burbot populations are highly affected by sea lamprey predation. Sea lamprey control programs must be effective for these species to be self-sustaining. Viral Hemorrhagic Septicemia has caused mass die-offs of fish. As one possible result of dreissenid mussels expansion, the native amphipod *Diporeia*, formerly a key food of a variety of fish species, has been extirpated (Fusaro and Holeck 2011), but a direct cause for the *Diporeia* spp. decline has not been established (Mohr and Nalepa 2005). Dreissenids also affect the populations of other species by altering nutrient and energy cycling, promoting nuisance algal blooms, and negatively impacting native species (Nalepa et al. 2011).

Asian carp, such as bighead and silver carp, have emerged as major potential threats because of their widespread distribution in the Mississippi River drainage, potential connections to the Great Lakes, and attractive and favorable habitats in Lake Erie, including Lake St. Clair. Consequences of an established population would include changes in plankton communities and biomass, reduced recruitment of fishes with early pelagic life stages, and reduced fish populations (DFO 2012). Recent environmental DNA samples have been found to be positive for Asian carp in Lake Erie (MDNR 2012).

The key terrestrial invasive species that was identified as a threat to Lake Erie is the non-native Common Reed (*Phragmites australis* subsp. *australis).* Common Reed creates monoculture stands in wetlands and beaches which often results in a decrease in biodiversity. This species is very common along the Lake Erie coast, dominates several large coastal wetlands and is continuing to spread.

Once established there are relatively few management options available to control these invasive species. Preventing entry of invasive species has often been cited as an approach to invasive species management. Once found, early detection and rapid response, one of the strategies described in some detail, may be employed to eliminate a species or work to minimize ecological consequences.

5.2.2. Why is non-point source pollution a critical threat?

According to the U.S. Environmental Protection Agency, non-point source pollution is the greatest threat to coastal waters (U.S. EPA 2012). Non-point source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from diffuse sources including both agriculture and urban areas. It has increased in recent decades, in contrast to the decline in pollution from point sources (Dolan et al. 2005). This kind of pollution is caused by rainfall or snowmelt moving over and through the ground and depositing the pollutants into water-bodies. In the LEBCS we have separated pollution from agricultural non-point sources and pollutants from urban point and non-point sources since they require different strategies to be abated.

5.2.3. Why is pollution from agricultural non-point sources a critical threat?

Pollution from agricultural non-point sources is a *High* ranked threat in all reporting units of Lake Erie (Table 5). These stresses impact most of the conservation targets of Lake Erie especially the Nearshore Zone, Coastal Wetlands, and Migratory Fish (Table 6). The worst conditions are found in the Western Basin and the Huron-Erie Corridor. This threat received a *Medium* rank for Native Migratory Fish in the deeper Central and Eastern Basins, as well as the Eastern Basin Connecting Channels, the Nearshore of the Central Basin, and the Coastal Terrestrial Systems in the Central and Eastern Basins (Table 6). The amount of pollution brought from agricultural lands into aquatic systems through overland flow is expected to increase as a result of climate change: Warmer air temperatures promote more intense storm events. Storms that produce more rain (in terms of amount per day, and number of consecutive days) increase rates of overland flow, which carry more sediments, nutrients, and pollutants into surface waters (see Appendix H). The influence of spring/summer rainfall on lake conditions was clearly demonstrated in 2011 and 2012. High rainfall in 2011 resulted in record pollutant loads and algal blooms in Lake Erie, In contrast, drought conditions in 2012 significantly reduced the nonpoint load to the lake, and a much less extensive algal bloom was seen in the western and Central Basins.

Table 5: Overall threat ranks for agricultural sources of pollution in reporting units of Lake Erie

	Huron – Erie Corridor	Western Basin	Central Basin	Eastern Basin
Pollution: Agriculture sources	High	High	High	High

Table 6: Threat-to-target ratings agricultural sources of pollution in Lake Erie.

Reporting Units	Islands	Native Migratory Fish	Aerial Migrants	Connecting Channels	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
HEC	Medium	High		High		High	High	
W Basin		High				High	High	High
C Basin		Medium			High	Medium	Medium	High
E Basin		Medium		Medium	Medium	High	Medium	High

Lake Erie serves as habitat to a diverse assortment of aquatic species and unique ecological systems, and these components of biodiversity undergo stress resulting from the robust agricultural economy in place throughout much of the basin. Agriculture is more intensive in the Western Basin, and in southern Ontario, than in the Central and Eastern Basin drainage. Intensive, predominantly row crop agriculture, along with some livestock operations, extensive agricultural drainage systems have contributed to high loads nutrients and sediments. Nutrients and sediments from agricultural areas enter tile drains, ditches, streams, rivers and ultimately Lake Erie. This results in eutrophication and algal blooms, leading to *High* rates of algal decomposition (which depletes dissolved oxygen levels), causing a large anoxic zone in the Central Basin, major algal blooms in the Western and Central Basins and along Central Basin shorelines, habitat loss, drinking water problems, and economic damage to many coastal areas and lake users.

These problems have long been recognized among managers, scientists, and those with cultural or economic ties to Lake Erie (PLUARG 1978, IJC 1980, Ohio EPA 2010). A long history of degradation and recovery, most recently characterized by a dramatic and only partly understood rise in the dissolved phosphorus load, has resulted in growing interest in seeing Lake Erie recover again, evident in binational, state/provincial, and local efforts.

In the 2008 LaMP, Lake Erie beneficial use impairments are summarized using assessments over several years. These included:

- Fish & Wildlife Consumption Restrictions
- Degradation of Fish Populations
- Degradation of Wildlife Populations and Loss of Wildlife Habitat
- Fish Tumors or Other Deformities
- Animal Deformities or Reproduction Problems
- Degradation of Benthos
- Restrictions on Dredging Activities
- Eutrophication or Undesirable Algae
- Recreational Water Quality Impairments
- Degradation of Aesthetics
- Degradation of Phytoplankton & Zooplankton Populations
- Loss of Fish Habitat

While a Lake Erie-specific impairment summary has not been done since 2008, other Great Lakes experts have noted many continuing and similar problems, such as in the SOLEC indicator summary drafts of 2011 (SOLEC 2011).

Primary among the many challenges is the input of non-point source pollutants including sediments and nutrients, especially phosphorus (P). The problem already is being exacerbated by a trend towards more intense and frequent early spring storms. Hypoxia is linked to eutrophication: Bacterial decomposition of dead algae lowers dissolved oxygen on the lake bottom and increases hypoxic conditions in Lake Erie (U.S. EPA 2011) Both eutrophication and hypoxia are likely to worsen with climate change (see Appendix H). These problems are promoted by warmer water temperatures that promote algal growth and lower the oxygen holding capacity of water, and by a longer duration of the stratified period (less mixing of water) in the basins that stratify (Central, Eastern).

> "*Many shoreline areas around Lake Erie are again experiencing nuisance growths of the green filamentous algae Cladophora. Hypoxia/anoxia in the central basin hypolimnion is expanding both spatially and temporally. The increasingly eutrophic conditions may also be impacting the*

> *fishery. Walleye and yellow perch populations have been showing long term declining trends since the 1990s, and there has not been a good hatch of walleye since 2003*" (Ohio EPA 2010, p. 11).

The 2011 Annual Report for the Lake Erie LaMP states:

> "*Although it does not appear that total phosphorus loads are increasing lakewide, total phosphorus concentrations in the nearshore are, and significantly increased loads of soluble reactive phosphorus (a measure of the most biologically available form of phosphorus from nonpoint sources) have now been measured in the Maumee and Sandusky rivers. While the mechanisms behind these changes are areas of active scientific investigation, there is an urgent need now for coordinated and strategic nutrient management actions*" (U.S. EPA 2011, p. 2)

The Great Lakes Fishery Commission, Forage Task Group (2012), measures of total phosphorus have generally been increasing in the Western and Central Basins, and nearshore Eastern Basin: "*In four of the last five years, total phosphorus levels in the west basin have been in the hyper-eutrophic range*" (p. 42).

Agricultural practices are believed to be a significant reason for increased dissolved phosphorus discharged to the lake, especially in the Western Basin. Agricultural drainage is a means of transport of such pollutants to the lake. While there have been positive changes such as conservation tillage, other changes in agricultural practices over the decades, particularly through intensification, coupled with nutrient losses from non-sustainable farming practices, are assumed to be contributing factors to the increases in dissolved phosphorus loading (Ohio EPA 2010). Altered hydrology can be defined as the changes in flow regime associated with artificial drainage. In agriculture, the intent of such drainage is to remove water from fields as quickly as possible to improve equipment access, and allow for better crop growth and higher yields. For these agricultural settings, changes in the flow regime are the result of surface (ditches and channelized streams) and subsurface drainage (tiling) of fields. This drainage water carries phosphorus with it, both in dissolved and particulate forms as well as other pollutants. Losses of pollutants that sorb to soils tend to be more significant with surface than subsurface drainage (Blann et al. 2009). Tile drains promote infiltration of water, but soils that are drained in the Lake Erie basin are prone to phosphorus losses to streams and subsequently Lake Erie (U.S. EPA 2009b). Artificial drainage can augment "flashy" storm events, which erode downstream channels and carry more pollutants to the lake. Drainage management can be improved and changed but it is needed to help agriculture remain competitive.

While there are some environmental benefits to agricultural drainage (Blann et al. 2009) (e.g., the avoidance of soil compaction), some impacts should be considered and tradeoffs weighed. Ohio EPA (2011) and others (Blann et al. 2009) frequently cite artificial drainage as contributing to stream impairment and nutrient transport. Artificial drainage in Lake Erie tributary watersheds such as the Sandusky River can lead to increased amounts of sediment entering streams by either overland transport or increased bank erosion, with the deep trapezoidal channels keeping all but the highest flow events confined within the artificially high banks. "*As a result, areas that were formerly flood plains and* *allowed for the removal of sediment from the primary stream channel no longer serve this function"* (Ohio EPA 2004, p. 34).

Whether through better management of drainage or other means, it is imperative that agricultural Best Management Practices (BMPs) intended to reduce dissolved pollutants are not replaced by practices that might increase surface runoff and erosion, leading to soil losses that include particulate and bioavailable phosphorus. Appropriate BMPs will differ across the basins and locally. Research issues also will differ, and will need to be conducted evaluating potential tradeoffs and determining net BMP benefits.

5.2.4. Why are pollutants from urban point and non-point sources a critical threat?

While agricultural non-point source pollution is widely recognized to be one of the top threats to biodiversity in Lake Erie, there are number of other pollution sources that were considered by experts to be *Medium*- to *High* -ranked threats, including contaminated sediments, industrial point sources, household and urban non-point sources, and airborne sources (Table 7).

Table 7: Overall threat ranks for sources of pollution in reporting units of Lake Erie.

	Huron – Erie Corridor	Western Basin	Central Basin	Eastern Basin
Contaminated sediments	Medium	Medium	Medium	High
Pollution: industrial	High	Medium	Medium	Medium
Pollution: airborne sources	Medium	Medium	Medium	Medium
Pollution: urban and household sources	Medium	Medium	Medium	High

Municipal point sources of phosphorus have declined since the 1970s. Municipal nonpoint concentrations and loadings are significant but not as large as loadings from tributaries (primarily agricultural loads), and continue to contribute a substantial proportion of total phosphorus loadings to Lake Erie (Figure 29; Dolan et al. 2007). Further, increases in storm intensities associated with climate change (see Appendix H) are expected to increase threats related to pollution carried by stormwater, and overflows of combined sewage and stormwater handling facilities. Because these sources are closely related, both geographically (associated with urban and industrial areas) and administratively, experts at the December, 2011 strategy development workshop considered them collectively.

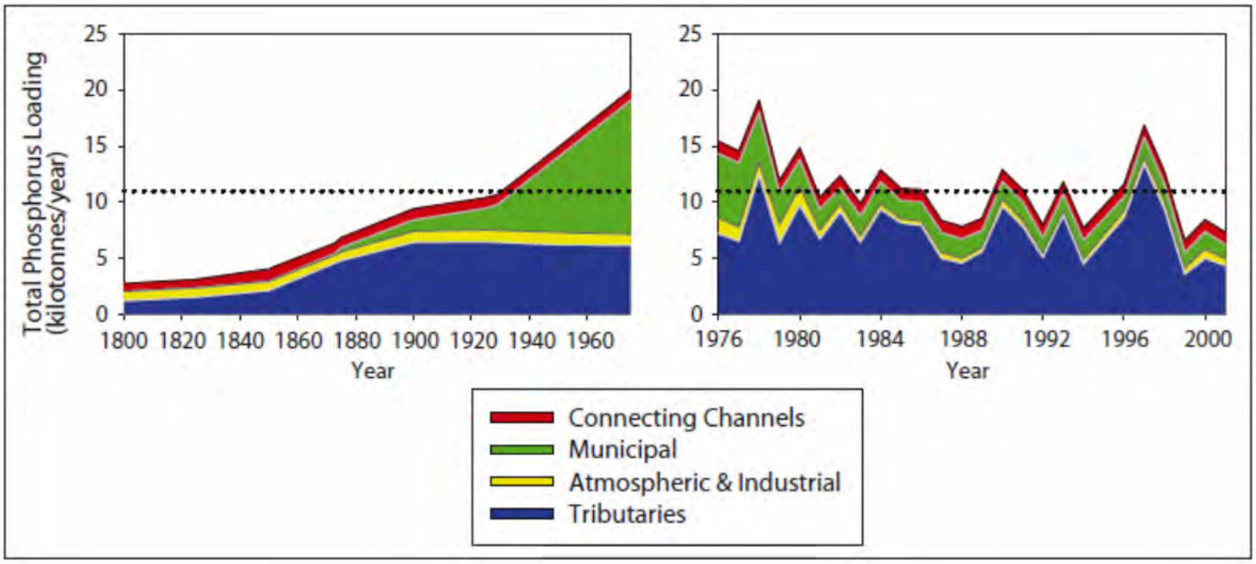

Figure 29. Total phosphorus loading to Lake Erie by source 1800-2002 (Dolan et al. 2007). Dotted line represents the phosphorus target for Lake Erie, as set in the Great Lakes Water Quality Agreement.

Contaminated sediments and pollutants from industrial, urban and household, and airborne sources generally were considered to pose a moderate threat to biodiversity conservation targets in Lake Erie (Table 8). The few *High* -ranked threats are limited to the Connecting Channels and include contaminated sediments and urban and household sources in the Eastern Basin and industrial sources in both the Eastern Basin and Huron – Erie Corridor. This pattern of threats reflects the high concentration industry and human population around the Connecting Channels. The impacts of contaminants from these sources on human health is better understood than the impacts to biodiversity, and while studies of toxic loadings in invertebrates, fish, birds, and other animals date back decades, it seems only the most dramatic impacts to biodiversity are well documented.

Table 8: Ratings of threat to each target for sources of pollution in reporting units of Lake Erie.

Reporting Unit	Islands	Native Migratory Fish	Aerial Migrants	Connecting Channels	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Offshore Zone
Contaminated Sediments								
HEC	Medium		Medium	Medium	Medium	Medium	Medium	
W Basin	Medium		Medium		Medium	Medium	Medium	
C Basin	Medium		Medium		Medium	Medium	Medium	
E Basin	Medium		Medium	High	Medium	Medium	Medium	

Reporting Unit	Islands	Native Migratory Fish	Aerial Migrants	Connecting Channels	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Offshore Zone
Industrial Sources								
HEC	Medium	Medium		High	Medium	Medium	Medium	
W Basin					Medium	Medium	Medium	
C Basin					Medium	Medium	Medium	Medium
E Basin				High	Medium	Medium		Medium
Airborne sources								
HEC		Medium				Medium	Medium	Medium
W Basin		Medium				Medium	Medium	Medium
C Basin		Medium			Medium	Medium	Medium	Medium
E Basin		Medium			Medium	Medium	Medium	Medium
Urban and household sources								
HEC	Medium	Medium	Low	Medium			Medium	Medium
W Basin	Medium	Medium	Medium			Medium	Medium	Medium
C Basin	Medium	Medium	Medium			Medium	Medium	Medium
E Basin	Medium	Medium	Medium	High		Medium	Medium	Medium

5.2.5. Why are housing and urban development and shoreline alterations critical threats?

Coastal development is land based human development near the coastal margins such as roads, residential, commercial, and industrial development, power plants, and wind farms. Shoreline alterations are human structures found along the shoreline or in the nearshore created to protect property, prevent erosion, trap coarse sediment, create safe harbors, and/or provide for safe water transport. Shoreline structures come in many different forms and include: rip rap, bulkheads, jetties, groins, piers, gabions, and seawalls.

Over time, the conversion and fragmentation of coastal areas due to residential and urban development has led to staggering losses and degradation of Coastal Wetland and Terrestrial Systems, as well as altered migration patterns for birds and fish. 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. In addition to these losses of habitat and function that have already occurred, fragmentation of natural systems reduces the capacity of coastal species to respond to climate change by reducing the likelihood of species movements along the shoreline. Similarly, development along the shoreline, and shoreline hardening have the potential to constrain inland movement of coastal systems in response to potential increases in lake level; alternatively, if lake levels drop, it is possible that some more natural conditions can develop as systems move lakeward (see Appendix H for discussion of possible lake level changes).

The single most important anthropogenic factor impacting the Nearshore and Coastal Terrestrial System is incompatible shoreline development and the resulting physical alteration of the land-water interface (SOLEC 2009). Physical processes such as littoral flow and sediment transport create and maintain the structure and function of Coastal Wetlands, Coastal Terrestrial, Nearshore and Island habitat and drive many species assemblages (Scheuerell and Schindler 2004), including fish populations and richness (Brazner 1997). Lake bed modifications due to jetties, groins, piers and shoreline armoring not only disrupt important sustaining physical processes, they may facilitate invasions of nearshore aquatic invasive species. Development also increases surface runoff (another critical threat addressed elsewhere) and reduces groundwater recharge due to “hardening” of the landscape. Runoff from impervious surfaces often contains chemical contaminants, nutrients, and fine-grained sediments that can adversely impact nearshore habitat structure and ecosystem function (SOLEC 2009). As we expect to see continued increases in the intensity of peak storm events (see Appendix H), the importance of runoff as a source of stress on coastal systems is likely to increase.

The initial threat assessment for Lake Erie indicated that Housing/Urban Development and Shoreline Alterations were ranked as *Medium* to *High* threats to biodiversity across the four reporting units, with both ranking as *High* threats in the Huron-Erie Corridor, Western Basin, and Eastern Basin. Similar to some of the other threats, The Steering Committee recommended that since these two threats were so similar in their nature, that they should be combined and addressed together rather than individually. As a result, the Steering Committee agreed that a new category of Coastal Conservation should be developed for addressing these two threats through the development of conservation strategies.

The threat of housing and urban development ranged from *Medium* to *High* in its potential impact to the following five targets: Aerial Migrants, Islands, Coastal Terrestrial Systems, Connecting Channels, and Coastal Wetlands (Table 9). Coastal Terrestrial, Coastal Wetlands, and Connecting Channels were the three targets that received the highest rated threats from housing and urban development. The threat of shoreline alteration ranged from *Medium* to *High* in its potential impact to the following five targets: Islands, Coastal Terrestrial, Coastal Wetlands, Connecting Channels, and the Nearshore Zone. The highest threat rating (high) from both the shoreline alterations and housing and urban development threats occurred in the Huron-Erie Corridor and Western Basin for the Nearshore, Aerial Migrants, Coastal Terrestrial, Connecting Channels, Islands, and Coastal Wetland targets (Table 10)

Table 9: Overall threat ranks housing and urban development and shoreline alterations in reporting units of Lake Erie

	Huron – Erie Corridor	Western Basin	Central Basin	Eastern Basin
Housing/urban development	High	High	Medium	High
Shoreline Alterations	High	High	Medium	High

Table 10: Threat-to-target ratings for housing & urban development and shoreline alterations in Lake Erie.

Reporting Unit	Islands	Native Migratory Fish	Aerial Migrants	Connecting Channels	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
Housing & Urban Development								
HEC	Medium		Medium	High			High	High
W Basin	Medium		High				High	High
C Basin	Medium		Medium				Medium	Medium
E Basin	Medium		Medium	High			High	Medium
Shoreline alterations								
HEC	High			High		High	High	High
W Basin	High					High	High	High
C Basin	Medium					High	Medium	Medium
E Basin	Medium			High		High	High	Medium

5.2.6. Why are dams and barriers a critical threat?

In Lake Erie, dams and barriers and diking of wetlands were treated separately in the threat rankings. As a result, with the exception of two instances, this threat was ranked as *Medium* across all targets and across all geographies. The exceptions were that the threat to Migratory Fish was ranked *High* in the Western Basin of Lake Erie and the threat to the Nearshore Zone was ranked *High* in the Huron-Erie Corridor. Based on a discussion with the Lake Erie Steering Committee, we elected to consider these two threats together and elevated them as critical and warranting strategies to address them in the December 2011 expert workshop.

Table 11: Overall threat ranks for dams and other barriers and diking of wetlands in reporting units of Lake Erie.

	Huron – Erie Corridor	Western Basin	Central Basin	Eastern Basin
Dams & other barriers	Medium	Medium	Medium	Medium
Diking of wetlands	Medium	Medium	Medium	Medium

Dozens of native Lake Erie fish species have (or historically had) populations that migrated into tributaries to spawn (Trautman 1981). But only 36% of Lake Erie tributary habitats are currently accessible to Lake Erie fishes due to blockage from dams. An unquantified portion of those are inaccessible due to other barriers such as poorly installed road-stream crossings. Similarly, most of the remaining coastal wetlands in Western Lake Erie (~85%) are diked (Johnson et al. 1997) and are therefore not accessible to nearshore aquatic communities and for nearshore processes. This is problematic since most Great Lakes fish utilize (sometimes require) coastal wetland habitats for at least a part of their life cycle (Jude and Pappas 1992). Other aquatic organisms also depend upon connectivity among these habitats, including imperiled freshwater mussel assemblages that depend upon a wide variety of fish to complete their juvenile stage and for dispersal (Nichols and Wilcox 2001, Sietman et al 2001). Some dykes do however play and important role in protecting Coastal Wetlands and by allowing water levels to be controlled which can support some management goals.

Tributaries play a key role in shaping nearshore habitats and providing important materials and nutrients. When tributaries are blocked by dams or other barriers, the delivery of materials such as sediment, woody debris or nutrients is disrupted. Loss of coarse nearshore sediments is a major problem in many areas in Lake Erie (O'Brien et al. 1999, Shabica et al. 2004, Garza and Whitman 2004, Meadows et al. 2005) and dams can contribute to that since coarser bedload sediment are trapped behind them (Roberts et al. 2007, Csiki and Rhoads 2010, Morang et al. 2011). Barriers can also modify the downstream temperature regime (Lessard and Hayes 2003). These disruptions can fundamentally change the character of the watershed and the nearshore areas adjacent to the mouth of the river (Fuller 2002, Postel and Richter 2003, Morang et al. 2011). As a result, dams and other artificial barriers can impact ecosystem services resulting in substantial socio-economic impacts to people (Richter et al. 2010).

Table 12: Ratings of threat to each target for dams and other barriers and diking of wetlands in reporting units of Lake

Reporting Unit	Islands	Native Migratory Fish	Aerial Migrants	Offshore	Connecting Channels	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
Dams & other barriers								
HEC		Medium					Medium	Medium
W Basin		High					Medium	Medium
C Basin		Medium					Medium	Medium
E Basin		Medium					Medium	Medium
Diking of wetlands								
HEC		Medium				High	Medium	Medium
W Basin		Medium				Medium	Medium	High
C Basin		Medium				Medium	Medium	Medium
E Basin		Medium				Medium	Medium	Medium

5.2.7. Why is climate change considered a threat?

Global climate change is already contributing to five major types of changes in the Lake Erie watershed: 1) increased air and summer surface water temperatures; 2) increased duration of the stratified period in basins of the lake that stratify; 3) flashier precipitation (increases in the intensity of storms, and drier periods in between); 4) decreased ice cover; and 5) changes in several factors that influence lake levels. Changes in wind strength and direction observed over the last few decades may also be linked to changes in climate, and are highly relevant in this system due to the strong link between wind, stratification, and the potential for hypoxia ("dead zones"). As increases in global temperature accelerate, we can expect the pace of many if not all of these current trends to increase. Climate-related factors act as important drivers of ecological processes in lake systems, and many can limit the suitability of Lake Erie habitats for key targets, or increase the threat associated with current stressors (i.e., invasive species, algal blooms, hypoxia in shallow zones of the lake). As the shallowest, warmest Great Lake, Lake Erie has the highest productivity, and supports species assemblages that reflect these warmer temperatures. Looking to the history of algal blooms and hypoxia in Lake Erie may also give us good ideas on what to expect as the other lakes rapidly warm, and as the intensity of storms increase, leading to higher runoff of nutrients that promote algal. As the challenge of dealing with hypoxia in

Lake Erie over the past several decades indicates, climate factors and land use factors often interact with one another, complicating our ability to anticipate future trends and impacts. Variability in climate change projections, especially possible changes in precipitation, which contributes to uncertainty in future lake levels and amount of run-off, 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.

Table 13: Overall threat ranks for climate change in reporting units of Lake Erie.

	Huron – Erie Corridor	Western Basin	Central Basin	Eastern Basin
Climate: habitat shifting/ alteration	High	High	High	High

Table 14: Ratings of threat to each target for climate change in reporting units of Lake Erie.

Reporting Unit	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Connecting Channels	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands
HEC	Medium	Medium	Medium	Medium		High	Medium	Medium
W Basin	Medium	High	Medium			High	High	High
C Basin	Medium	Medium	Medium		Medium	High	High	High
E Basin	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High

6. STRATEGIES TO ABATE CRITICAL THREATS TO BIODIVERSITY

This chapter describes strategies to abate critical threats in Lake Erie and restore degraded ecological attributes. These strategies are the result of the Conservations Action Planning framework using a participatory approach. The strategies were developed using the best available information and expert opinion and are not meant to be static but to be improved through an adaptive approach to conservation planning (TNC 2007). The final set of five high priority biodiversity conservation strategies for Lake Erie that are dicussed in this chapter are:

1. Reducing the Impact of Agricultural Non-Point Source Pollutants;
2. Preventing and Reducing the Impact of Invasive Species (aquatic and terrestrial);
3. Coastal Conservation: Preventing and reducing the impacts of Incompatible Development and Shoreline Alterations
4. Reducing the Impacts of Urban Non-Point and Point Source Pollutants
5. Improving Habitat Connectivity by Reducing the Impact of Dams and Other Barriers

6.1. Identifying potential strategies and designing high priority strategies

To develop these strategies, a workshop was held that brought together 71 experts from academic institutions, NGOs, and government agencies (see Appendix B for a complete list of contributors). The workshop objectives were: 1) to develop strategies to abate key threats and restore biodiversity in Lake Erie and 2) to develop a results chain with objectives and indicators for each top-ranked strategy.

Participants were informed about the CAP process as well as about the results of the viability and threats assessments. Each of the critical threats from Box 8, except climate change, was the topic of a breakout group discussion. All breakout groups were asked to address climate change impacts on targets, threats, and strategy effectiveness in the development of their specific strategies. An expert familiar with current climate change trends and projections was included in each of the breakout groups and while impacts were not explicitly reviewed in the session, this expert and others familiar with the topic were encouraged to highlight situations where climate change would lead to new threats, or influence the priority or effectiveness of a strategy being discussed.

Using conceptual models[15], breakout groups analyzed the contributing factors to each threat, brainstormed strategies to address the most important contributing factors, and then identified the subset of strategies that would most likely be effective at abating the threats. The selection of the

[15] Figure 4 depicts the elements of a conceptual model or (or situation analysis)

priority strategies is based on the addition of the rating of its **feasibility** and **potential impact**[16]**.** For each of these high priority strategies, the groups then elaborated result chains[17], detailing the intermediate outcomes and assumptions associated with implementing the strategy, and identifying specific objectives and measures that would help assess the effectiveness of the strategy. In the strategy development process, we considered not only the threats to be addressed but also the Key Ecological Attributes that were most degraded (and therefore in need of restoration) for each affected target. This aspect of the process resulted in the incorporation of biodiversity restoration into each strategy (see Appendix I for more details on the methodology used during the workshop).

The revision process of the strategies extended for several months after the workshop, entailing numerous conference calls and webinars for each strategy with the participation of experts and Core Team members. The strategies were revised, modified and accepted by the Steering Committee through reviews of the strategy draft reports. Although the development of the strategies followed the same methods, it is important to highlight that due to the nature and complexity of each assessed threat and at the same time as an effect of the participatory process, the final products for each strategy may vary in terms of the detailed used to define results objectives and measures.

The set of strategies described in this chapter is to be considered as guidance for agencies, organizations, municipalities, and other managers and stakeholders engaged with biodiversity in Lake Erie. We did not attempt to set priorities among these, though perhaps some previous work by the Lake Erie LaMP Ecosystem Objectives Subcommittee suggests an overriding priority:

> *"Of the management levers examined in the model, those that affected the availability of natural, undisturbed land caused the largest response across the greatest number of variables. Therefore, the availability of natural lands was the key driver of the ecosystem clusters. Nutrient levels were the second most important influence but did not have the impact that natural land (habitat) had on the ecosystem. In other words, phosphorus can be strictly managed, but unless natural land or habitat is protected and restored, only marginal response will be seen by many components of the ecosystem. It was determined that changes in land use that represent a return towards more natural landforms or that mitigate the impacts of urban, industrial and agricultural land use, are the most significant actions that can be taken to restore the Lake Erie ecosystem."* (U. S. EPA 2008, p. 29)

This finding clearly points to restoration of natural lands as the most effective and critical set of strategies for improving the Lake Erie ecosystem. Given that 76% of the Lake Erie watershed has been converted from natural land cover to other types—predominantly agriculture at 62.5%—it isn't surprising that land cover has an overriding effect on all other strategies that might be employed. To restore targeted ecosystem attributes, processes, and functions, one has to restore supporting ecosystems; in the case of Lake Erie, that would be the watershed. Any restoration activities will need

[16] The rating process varied from breaking groups, some used qualitative measures and some quantitative measures.
[17] Figure 5 depicts the elements of a result chain.

to be targeted and strategic. Most of the basin is a working landscape that is dominated by very productive agricultural lands, and while watershed restoration is needed and will benefit the biodiversity and water quality of Lake Erie, large-scale restoration is unlikely to occur.

6.2. Reducing the impacts from agricultural non-point source pollution

Agricultural non-point source pollution is the contribution of excess runoff, nutrients, sediment, and other pollutants from agricultural lands that significantly exceed natural baseline levels and result in degradation of water quality and associated biological communities[18]. Recognizing that agriculture is responsible for the majority of the nonpoint source phosphorus load to Lake Erie (IJC 1980, Dolan and McGunagle 2005) and the extensive impacts, there is a need for near-term advancement. We developed two strategies to offer such near-term advancement and address the impacts from agricultural non-point source pollution:

> Strategy 1: target and intensify adoption of nutrient management BMPs to reduce dissolved and bioavailable phosphorus loadings to Lake Erie; and
>
> Strategy 2: promote surface and subsurface drainage options, policies and programs that reduce nutrient and sediment losses and delivery.

Participants felt that drainage options should be paid specific attention as possible sources and routes for nutrient and sediment and considered at the same time as nutrient Best Management Practices (BMPs). Surface and subsurface drainage options that keep some portion of the water on the land surface, particularly during low flow conditions, could 1) reduce nutrient and sediment losses and 2) might positively affect the flow regime or hydrograph. However, more research is needed to understand how well certain drainage options can reduce nutrient and sediment losses and delivery. This is why this strategy is less developed than Strategy 1, for which there has been more research and practice. It is imperative that agricultural BMPs aiming to reduce pollutants such as dissolved phosphorus are not replaced by practices that might increase surface runoff and erosion, leading to soil losses that include particulate and bioavailable phosphorus. Therefore, all practices should be researched and evaluated to avoid inadvertent losses through other routes – the unintended negative consequences of well-meaning efforts. Appropriate practices and research will differ across basins and locally, and there are gaps in our understanding. While there has been significant investment in managing water quantity in many urban areas (i.e. stormwater ponds), there is a need and opportunity to apply some of these approaches to rural settings.

[18] This already dominant and pervasive threat to the Great Lakes is likely to increase as several climate-change related factors (i.e., increased storm intensities that produce more run-off, the potential for agriculture to expand north, the potential for longer growing seasons, and the need for additional chemical treatments to address new or more challenging pest problems).

It also is critical to note that there is considerable uncertainty regarding the results of BMPs, with multiple confounding factors and research needs. There are time lags between implementation and detecting results at the field edge and tributary monitoring sites. Because nutrients accumulate in soil, stream sediments and floodplains, they will continue to be released even after new loading stops. Climate and changing agricultural trends can further confound results. The effectiveness of individual BMPs will vary depending on the management system they are applied to, but this is rarely accounted for in determining their effectiveness. Whether it be the targeting of BMPs, the application of the 4Rs (applying the right source of fertilizer in the right place, at the right time, using the right rate; http://www.nutrientstewardship.com), or implementation of new drainage practices to reduce nutrient losses, implementers must recognize this uncertainty, monitor their results, share information, recognize variations from intended results, and continually apply adaptive management for improvement.

In these agricultural strategies, the term "dissolved phosphorus" also includes the portion of particulate phosphorus that becomes bioavailable. Some references to "dissolved phosphorus" also add the term "bioavailable phosphorus" to make this point clear (see Box 9 for a description of different forms of phosphorus).

Box 9: Forms of phosphorus (description based on Bootsma et al. 2012; U.S. EPA 2009; Reutter et al. 2011; Pers. comm. R.P. Richards, Heidelberg U., September 2012)

Phosphorus is measured as many forms, each of which has its own importance for algal production. **Total phosphorus** includes all forms of phosphorus, and consists of two major portions: **dissolved phosphorus** is the phosphorus in water that passes through a filter with a certain pore size (0.45 micron), while **particulate phosphorus** is attached to particles that do not pass through the filter. Both of these can be chemically divided into various types, the most important of which is called **dissolved reactive phosphorus** (DRP). DRP (also referred to as SRP, soluble reactive phosphorus) is largely bio-available to phytoplankton, macro-algae, and macrophytes, while only about 30% of the phosphorus making up particulate phosphorus is bioavailable.

Particulate phosphorus can be divided into particulate **organic phosphorus** which is incorporated into living organisms and released through feces or when the organism dies, and p**articulate inorganic phosphorus** which is typically orthophosphate attached to particles, but can include mineral forms of phosphorus such as apatite.

6.2.1. Priority strategies

Non-point source pollution is diffuse in origin, and there are myriad factors contributing to its generation (Figure 30). At the December 2011 workshop, experts identified several groupings of factors including Best Management Practices (BMP) funding issues and implementation, erosion factors, drainage infrastructure, cropping trends, nutrient management, nutrient application and climate change-related increases in peak storm events. They also highlighted the importance of how other contributing factors (such as livestock densities, lack of coordination, biofuels, commodity prices, profit margins and degraded soils) interact to contribute to pollution. These factors also offer multiple opportunities to influence land management behavior toward better outcomes for water quality. Workshop experts identified about twenty possible strategies from which the top two strategies emerged as high priorities (Table 15). These strategies include combining some of these individual possible strategies. Also, any strategies, including that under the Binational Nutrient Management Strategy (Lake Erie LaMP 2011), and in response to the GLWQA of 2012 (IJC 2012), will be developed at the appropriate and relevant state, provincial or local context. Note also that participants identified responses by farmers to climate change (i.e., changes in crops grown, increases in the use of irrigation to address increasing drought stress) as emerging issues, but ones that were beyond the scope of this document at this time due to insufficient information.

Table 15: Priority strategies for reducing the impacts from agricultural non-point source pollution in Lake Erie. Tier 1 strategies were considered of highest priority and were selected for more detailed strategy development. Tier 2 strategies are also important to address this threat.

Strategies	Priority
Target and intensify adoption of nutrient management	Tier 1
Promote surface and subsurface drainage options, policies and programs that reduce nutrient losses and delivery	Tier 1
Use information sharing and education	Tier 2
Communicate cost-benefits to increase awareness	Tier 2
Identify sources of funding	Tier 2
Use market based solutions	Tier 2
Isolate hotspots for 319/ Total Maximum Daily Load (TMDL) implementation	Tier 2
Coordinate TMDL implementation	Tier 2
Promote on-field management of drainage	Tier 2
Harness federal dollars to reduce NPS	Tier 2
Promote new innovative agriculture equipment	Tier 2
Practice large scale water retention/runoff management	Tier 2
Coordinate program/project implementation	Tier 2
Implement the Farm Bill and Canada-Ontario Environmental Farm Plan	Tier 2
Target BMPs	Tier 2
Implement mechanisms to increase BMP implementation	Tier 2
Promote watershed based use of specific BMPs	Tier 2
Implement designs to provide filtering of sediments and attached pollutants (e.g., Blind inlets phosphorus trap)	Tier 2
Implement nutrient recapture and stockpiling practices	Tier 2

*The applicability of each of these strategies would depend on each country or region within Lake Erie. Many of the “Tier 2” strategies are actually covered in this document, as they are included within the two “Tier 1” strategies.

Agricultural pollution comes from different sources (e.g., commercial fertilizer, manure) and from different activities (e.g., row cropping, livestock operations) in addition to the different routes or pathways (e.g. surface and subsurface drainage). Beyond this, the importance of each route and the combinations of sources, activities, routes and appropriate BMPs varies regionally. For example, tile drainage is more prevalent on the flat landscapes that dominate in the Western Basin. These variations are particularly important in the context of understanding the mechanism of the threat, so that the most appropriate BMP can be identified and applied to address a specific situation. Agricultural strategies for conservation are expected to differ among basins. Efforts are currently underway to improve the understanding of how BMP effectiveness may vary in different settings. For instance, the Grand River Water Management Plan is an initiative in the Ontario portion of the Eastern Basin that will support better watershed management by highlighting the role of different sources and pathways of nutrients (GRCA 2010).

6.2.2. Strategy 1: Target and intensify adoption of nutrient management BMPs to reduce dissolved and bioavailable phosphorus loadings to Lake Erie

Conservation Best Management Practices (BMPs) have long been recognized as a way to prevent, control and treat pollutants related to agriculture. This strategy reflects both the broadly recognized need to make BMPs more effective, and to know how and where to target the implementation of agricultural BMPs.

Two ways that water quality information is used for targeting BMPs is through the use of monitoring and modeling. Most outstanding is the tributary monitoring of Heidelberg University, which measures the total amounts (loads) of pollutants exported from watersheds and to the lake (Richards et al. 2007; Baker 2010). The Ontario Ministry of the Environment‘s Provincial Water Quality Monitoring Network for the Grand and Thames Rivers has collected data to both spatially and temporally identify broad trends in the transport and delivery of nutrients to Lake Erie (Cooke and Maaskant 2010). Modeling efforts include SPARROW (SPAtially Referenced Regressions On Watershed attributes – USGS estimates pollutant total annual loads and concentrations (Smith et al. 1997; Robertson and Saad 2011)), SWAT (Soil and Water Assessment Tool - USDA and partners predict the effect of management decisions on water, sediment, nutrient and pesticide yields (Bosch et al. 2011; Daloglu et al. 2012; ERCA 2011)), and TMDLs (Total Maximum Daily Loads - state agencies and U.S. EPA assess stream and lake conditions and estimate needed pollutant reductions (e.g., Ohio EPA 2012a)). The Grand River, Ontario, plume has been modeled to describe in-lake pollutant distributions (He et al. 2006). Modeling is also used to estimate lake phosphorus variability and estimate the contribution of tributaries to concentrations in the lake (Schwab et al. 2009). Monitoring and modeling can help determine where the greatest loads originate, help focus limited resources and help make them more effective. These types of tools can be used from the field (e.g., edge of field monitoring) to basin-wide scales. Monitoring and modeling also are underway to understand the mechanisms by which phosphorus is delivered to the lake from areas.

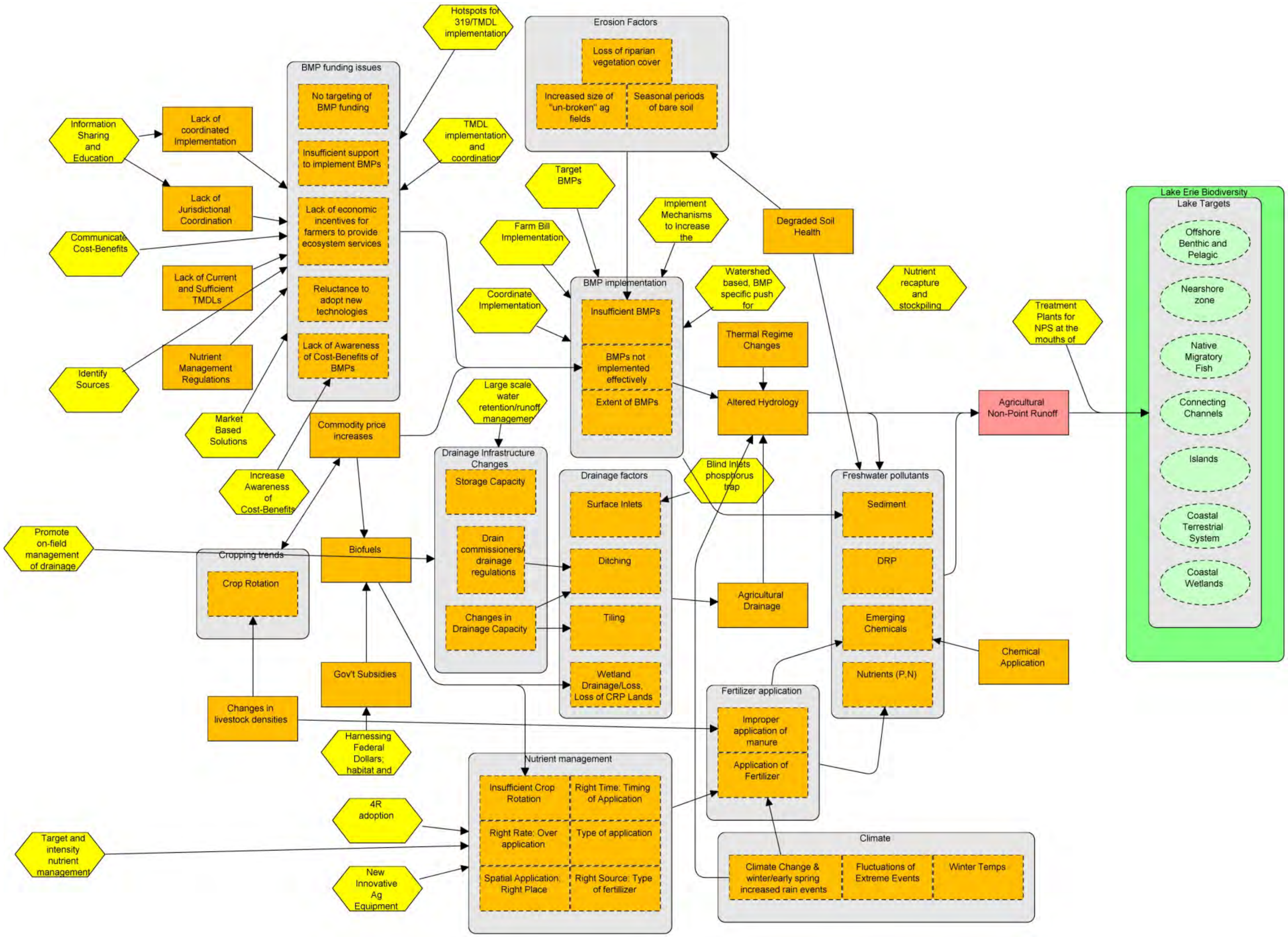

Figure 30: Conceptual model of agricultural non-point sources of pollution in Lake Erie

previously less well studied but with regionally significant contributions (e.g., Grand River, Ontario). These efforts are important to understand where loads originate and the mechanisms involved, so that the most effective BMPs can be identified and implemented (GRCA2010).

In addition to monitoring and modeling, other innovations related to BMPs are constantly growing and being advanced. While control and treatment BMPs are continually emphasized, scrutinized and refined, there is growing interest in focusing on the use of fertilizers and avoiding the loss of nutrients from the agricultural fields. These BMPs include the adoption of the "4Rs" of nutrient stewardship (applying the right source of fertilizer in the right place, at the right time, using the right rate) as a way to optimize the efficiency of fertilizer use. While agricultural BMPs are extensively applied and have a long history of implementation, there remains a need to improve their effectiveness. While not a new concept, the 4Rs recently have received more emphasis as part of the solution to reducing losses of fertilizer and nutrients. A coalition of organizations are promoting the program, led by The Fertilizer Institute, the Canadian Fertilizer Institute, and the International Plant Nutrition Institute and including other businesses, government agencies and NGO partners (http://www.nutrientstewardship.com). During meetings and through comments on the Lake Erie BCS agricultural strategies, participants offered many strategies that included BMPs. In Ontario, for example, the program is receiving attention in the Grand River watershed (https://collaborase.com/Farming4RWatershed). Because of growing agricultural interest and concern regarding accurate adoption of the nutrient management practices, 4R Nutrient Stewardship received the most emphasis in the LEBCS strategies.

Implementation of and training in the 4Rs need to focus on agricultural retailers, crop advisers, service providers, nutrient applicators and farmers. These parties must work together when planning application rate, timing, placement and source of nutrients. Farm managers make the final decisions about nutrient application and due to past experiences or financial resources the final management decision may deviate from the advice given by their service providers. A strategy focused on any party engaged in fertilizer management, such as fertilizer dealers, must be supplemented by other education and implementation, including information on how past performance of BMPs may differ under warmer climates with more intense storms. Strategies must be planned to reach and be implemented by all involved.

Strategic actions

Based on input from expert participants and reviewers, below is a recommended approach outline to integrate the targeting BMPs and implementing 4Rs. This outline offers a stepwise approach to supplement the conceptual model (Figure 31) and results chain (Figure 32) for these strategies.

1. Determine with whom and where to target the implementation of practices. (See Result 1 in Figure 31: Results chain for the Nutrient Management Strategy in Lake Erie, below)
2. Determine the most appropriate BMPs for implementation at each site (including the 4Rs as part of the mix). (See Result 4 below)

3. Assess the likely response to implementing the BMPs, so that resources can be targeted to where they will result in the greatest improvement (these areas might not be the area with the greatest loading).

4. Develop a coordinated program of education, promotion and support to encourage adoption of appropriate BMPs in targeted areas. (See Result 3 below)
5. Identify barriers to adoption of the BMPs, so that resources are not wasted promoting practices that will fail because of lack of support. (See Result 4 below)
6. Assess the rate of adoption. (See Result 4 and 5 below)
7. Assess amount of nutrient runoff and agricultural non-point pollutants and stressor-response (algae, dissolved oxygen, etc.) (See Result 5 below)

Results, objectives and measures

The actions taken to implement this strategy will produce several important intermediate results (Figure 22). There is a chain of results that follows, summarizing the primary focus of this strategy on nutrient application and BMPs, including the 4Rs. That primary results chain is described below.

Result 1. Know with whom and where to target the implementation of practices.

Targeting leads to focusing resources on subwatersheds and even specific fields to improve nutrient application practices. For the Western Basin—the source of a large fraction of the agricultural nutrients flowing into Lake Erie—this could mean focusing on a subwatershed that is determined to contribute a relatively large part of the pollutant load, or it could mean a combination of factors. One recently targeted subwatershed in the Maumee River basin has been the Blanchard River subwatershed in Ohio. The Grand River, Thames River and Essex Region watersheds have been targeted in Ontario. For example, the Grand River Conservation Authority has launched a new rural-urban partnership to protect water quality and support Ontario agriculture. The partners include many agencies, farm organizations and the private sector (GRCA 2010). The Binational Nutrient Management Strategy (U. S. EPA 2011) also lists priority watersheds that are above phosphorus targets and require focused total phosphorus concentration reductions.

Objectives associated with this result are:

Objective 1. By 2016, all areas within priority watersheds are identified for focus of farm-based nutrient management efforts. Identify the watersheds / sub-watersheds (Hydrologic Unit Code (HUC))/ hydrologic response units (HRUs) that are contributing the most bioavailable phosphorus (P) to the lake. Targets could be set for either concentration or quantity, or both.

- Measure 1: Lake-wide consensus and map of priority watersheds.
- Measure 2: Key individuals and champions are in place, trained and train others.

Objective 2. Identify the source (including urban/residential/other) and transport factors within the HRU that are leading to high P losses.

- Measure 1: Contributions from nutrient sources are quantified.

Objective 3. *Identify the areas within the HUC/HRU that are the critical source areas. These should be the highest priority for implementing BMPs*.

- Measure 1: Specific HRUs are identified.

Result 2: Available resources are more effectively designated.

- Measure 1: Outreach and education are targeted.

Federal and other programs that provide financial support to farmers are limited, and effectiveness of pollutant reductions from BMPs varies, so there is a need to specify target areas. There may be a need to specify watershed size (Hydrologic Unit Code (HUC) size), and that could be determined by the available information relative to the prioritization criteria. Some watersheds (e.g., Blanchard River (Maumee basin), Grand River, Thames River and Essex Region watersheds) are already prioritized for action, but smaller watersheds need to be identified based on technical criteria within these relatively large areas. To better achieve this objective of targeting, there is a need for more data from tributaries and for criteria based on monitoring and/or modeling. The results of ongoing studies (e.g., SPARROW, SWAT, TMDLs) could inform these criteria, and show where resources could be most effectively used. There may be some benefit to showing farmers the nutrient balance and where emphasizing reduction of losses is most cost-effective.

Box 10: HUCs and HRUs

Hydrologic unit codes (HUCs) are standardized multi-digit code for watershed boundaries organized in a nested hierarchy by size (http://nwis.waterdata.usgs.gov/tutorial/huc_def.html).

Hydrologic Response Units (HRUs) are portions of a subbasin that possess unique combinations of land use, management, and soil attributes (http://geo.arc.nasa.gov/sge/casa/swat.html), and runoff is calculated for each HRU.

Result 3: Outreach and educational programs are coordinated and effective

Because there are changes and growth in knowledge, and uncertainty on BMP effectiveness and what the best approaches are, there will be a need for a BMP outreach and educational program that are coordinated. This need will be binational and reach across many organizations and agencies, from national to local. It is essential that effectiveness of BMPs, including the 4Rs, is included, and that the latest, most reliable information is transferred and used by both government and nongovernmental organizations. Organizations will have to ensure that personnel are aware of and use the best information on BMPs and are continually seeking more information on effectiveness. There needs to be a system for sharing information and training, and measurement to determine that it is effectively applied.

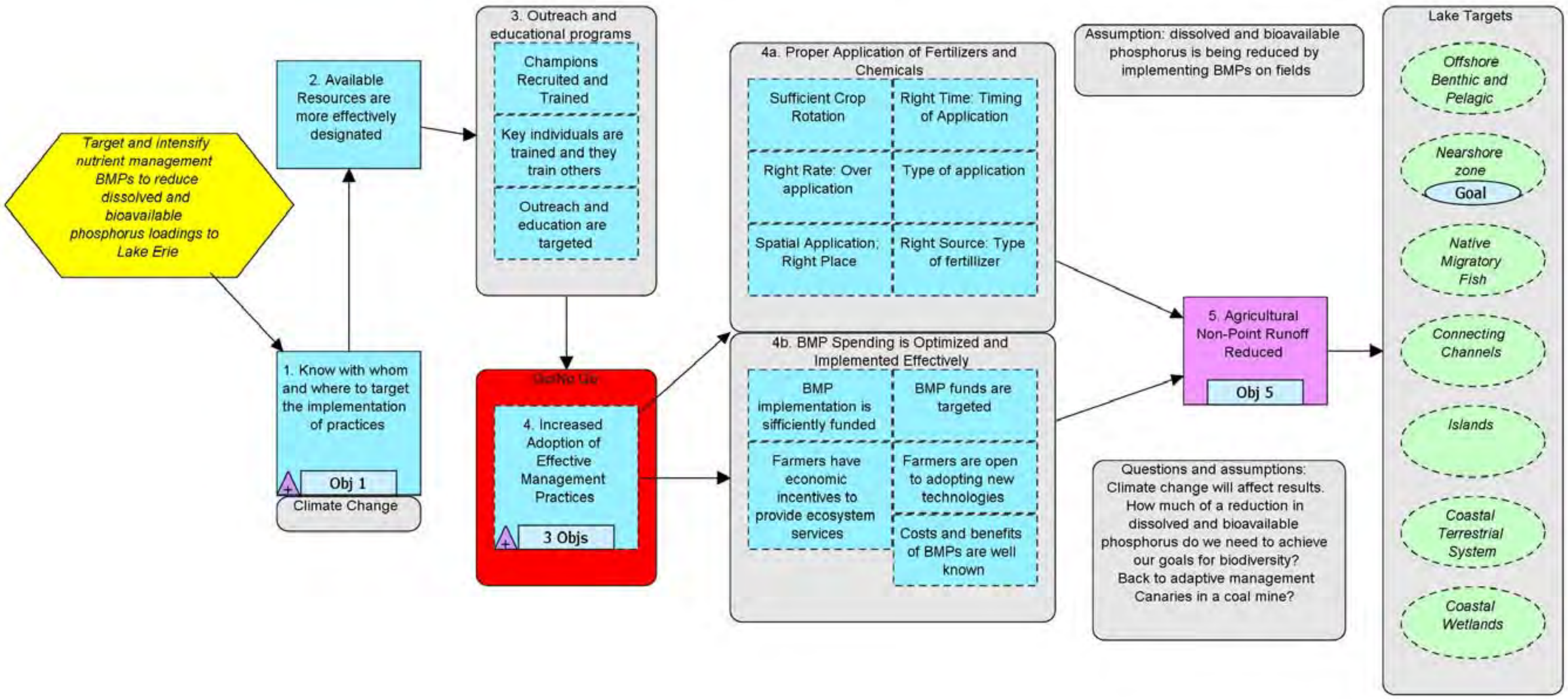

Figure 31: Results chain for the nutrient management strategy in Lake Erie.

Result 4. Increased Adoption of Effective Management Practices

This result is a 'Go/No-go' step in the process; if farmers don't adopt effective nutrient management practices, the strategy will fail. To better achieve success, there are three objectives associated with this result.

Participants emphasized the need to optimize and effectively implement BMP spending, as highlighted in Result 4a in Figure 31. At the same time, the increased focus on proper application of fertilizers and chemicals, as exemplified by the 4R program and its recent emphasis, also is specifically addressed in Result 4a. As noted in this document, BMPs in Results 4a and 4b are simultaneously considered and addressed.

Objective 1: By 2014, effective BMPs, including the rate, place, and timing of nutrient applications, for all crops, are better defined and agreed upon.

- Measure 1: Universities and agencies are helping to define and have consensus on effective BMPs and the 4Rs.
- Measure 2: State/provincial/university fertilizer guidance documents are updated.

The universities and agencies will determine effective BMPs, including the 4Rs. For designing the approach, peer reviewed and agency research is acceptable. Ongoing research could provide updated fertilizer guidance such as the Tri-State Recommendations (Vitosh et al. 1995) or Ontario's Agronomy Guide for Field Crops (http://www.omafra.gov.on.ca/english/crops/pub811/p811toc.html). Because crop genetics and climatic conditions are changing rapidly, this information should be updated at least every 10-20 years. There is a need for more discussion among agronomic, industry, and environmental stakeholders to agree on tradeoffs and determine barriers affecting capacity to implement the 4R approach. The State of Ohio formally called for these efforts in 2012 (ODNR 2012).

Objective 2: *By 2015, a nutrient stewardship certification for nutrient service providers is developed and adopted the Lake Erie basin*.

- Measure1: Number of service providers certified (including agricultural retailers and crop advisers).
- Measure2: Number of acres under 4R certified management and/or number of Regional Water Quality Projects completed

In Ontario, Conservation Authorities are implementing the Rural Water Quality Program (RWQP) in conjunction with municipal, provincial and federal governments. The number or RWQP projects including nutrient management such as the 4R program also could be a measure of progress. Such programs are developed with the advice and assistance of farm organizations.

Voluntary certification for environmental purposes is common in many sectors, including manufacturing, forestry and some agriculture (e.g., http://www.sba.gov/content/green-certification-and-ecolabeling). The benefits are many, including a competitive advantage when marketing/selling products. Typical to these programs is the development of an agreed upon set of standards that an entity needs to meet to achieve certification. Third-party evaluators generally compare actual management against the standards, provide feedback on what, if anything needs to be changed to meet standards, and when satisfied issues a report recommending certification to a governing body. Another advantage of a certification program is the enhancement of customer service, focused on reducing the customers' fertilizer losses. As government agencies scrutinize agricultural activities in the Lake Erie basin, an agricultural retailer certification could provide agribusinesses with a line of defense against legal or regulatory actions, albeit a designation currently lacking in legal authority.

A coalition of organizations engaged in fertilizer management in the Lake Erie basin has been formed and is working toward a goal of establishing a 4R certification program. As already mentioned, this coalition is led by The Fertilizer Institute, the Canadian Fertilizer Institute, and the International Plant Nutrition Institute and including other commercial partners, governments and NGOs (http://www.nutrientstewardship.com; www.collaborase.com/4RWatershed). Among the components under consideration would be: (1) a requirement that all 4R-certified entities would need to have a CCA (certified crop advisor) approve all nutrient recommendations; and (2) specific education on the 4Rs, including soil sampling.

Retailer certification would rely on the identified best management practices related to the 4Rs in which the retailers have influence over. Watershed models could help predict specific environmental benefits from specific best management practices. The certification program should include commercial fertilizer and manure management; it is possible that the Indiana fertilizer applicator certification system may provide a model (Office of Indiana State Chemist 2011).

Retailers who implemented defined practices, and were then determined to be in compliance with standards by third-party verifiers, would be able to advertise themselves as certified retailers.

Acres affected by retailers vary considerably, so overall acres covered under certification could be a more effective measure. Another measure would be percentage of fertilizer applied under certification. Certification of retailers has uncertainties concerning what certification would entail and what the resulting impact would be.

Other measures could include "CCA programs in place" or "tonnage of fertilizer delivered."

Objective 2: *By 2018, 100% of certified retailers are educated in and applying nutrient management following the 4Rs*.

- Measure 1: 4Rs incorporated in certified crop advisors (CCA) and other service provider curricula

Result 5. Agricultural non-point runoff is reduced

The preceding results should lead to the outcomes of reduced nutrients in runoff from agricultural fields and delivered to the freshwater systems—especially the Nearshore Zone—that are biodiversity conservation targets. These results would lead to an improvement in the viability of the Nearshore

Zone, the conservation target most threatened by agricultural non-point source pollutants. There is one objective associated with this result.

> Objective 5: *Based on multi-year averages, reduce the load of dissolved phosphorus by 50% by 2030 in at least the priority watersheds.*

- Measure 1: Annual loads of dissolved phosphorus
- Measure 2: Nearshore target; concentration of 15 ug/L in the Western Basin of mean annual total phosphorus (as provided in LaMP documents (U.S. EPA 2009b; IJC 2012))

This Strategy recommends a 50% reduction in the load of dissolved phosphorus. This reduction objective reflects the recent review by Reutter et al. (2011), which compared mid-1990s levels of dissolved phosphorus loads to the condition of Lake Erie at that time, i.e., the fish community was considered to be relatively healthy, and Harmful Algal Blooms were limited. Since then, dissolved phosphorus loads have increased significantly, as shown in the Heidelberg University monitoring results in Figure 12.

> "*While total P (phosphorus) loading has not increased significantly in the last 15 years, the loading of dissolved P is back to the levels of the early 1970s, and it is possible that a 2/3 reduction in the current loading of dissolved P will again be required to control the problem"* (Reutter et al. 2011, p. 4).

Participants in this Strategy felt that a 50% reduction by 2030 was reasonable given the complexity and scope of the reduction task, and that adaptive management should be applied if this reduction amount or time goal was determined to be inadequate or inappropriate. Participants also emphasized adaptive management; it was expected that attempts will be made, and adjusted, on an ongoing basis to set phosphorus targets in priority watersheds.

In comparison, the Great Lakes Restoration Initiative Action Plan (GLRI 2010) includes measures of progress with a goal that nearshore waters are not impaired. Through 2014, these measures' targets include reduction of the "*Five year average annual loadings of soluble reactive phosphorus from tributaries draining targeted watersheds*" (p. 29). Annex 3 - Control of Phosphorus of the Great Lakes Water Quality Agreement of 1978 includes "*the reduction by 30 per cent of phosphorus introduced from diffuse sources into Lakes Ontario and Erie, where necessary to meet the loading allocations to be developed* …" (IJC 1978; http://www.ijc.org/rel/agree/quality.html#ann3). While progress has been made on reducing particulate phosphorus loads to Lake Erie, dissolved and bioavailable phosphorus remain problematic and vary considerably from year to year. For example, 2011 nonpoint source loads from Lake Erie's tributaries were among the highest while 2012 loads thus far are among the lowest, especially during the critical springtime period (Pers. comm., R.P. Richards, Heidelberg University, August 2012). The above 50% reduction goal would be expected to be based on a multi-year average. In October 2012, Environment Canada (2012) announced the $16 million Great Lakes Nutrient Initiative, helping to address the complex problems of recurrent toxic and nuisance algae, and nearshore water quality and ecosystem health. The focus will be on Lake Erie, including nutrient loadings from selected Canadian tributaries; knowledge of the factors that impact tributary and nearshore water quality, ecosystem health, and algae growth; and binational lake ecosystem objectives, phosphorus objectives, and phosphorus load reduction targets.

State and provincial level actions also are expected to play key roles. For example, in recognition of these new and existing nutrient and algal bloom problems, Ontario's proposed Great Lakes Protection Act would authorize the Minister of the Environment to set targets and further the development and implementation of initiatives (http://www.ene.gov.on.ca/environment/en/subject/great_lakes/STDPROD_096895.html). Ontario's Draft Great Lakes Strategy discusses ways the province is addressing them (http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_096950.pdf)

Annex 4 of the GLWQA of 2012 (IJC 2012) includes total phosphorus concentrations and load targets for Lake Erie, and states:

> "*In establishing Substance Objectives for phosphorus concentrations and phosphorus loading targets, the Parties shall take into account the bioavailability of various forms of phosphorus, related productivity, seasonality, fisheries productivity requirements, climate change, invasive species, and other factors, such as downstream impacts, as necessary.*
>
> *The Parties shall complete this work for Lake Erie within three years of entry into force of this Agreement and complete this work for the other Great Lakes on a schedule to be determined by the Parties.*
>
> *The Parties shall periodically review the Substance Objectives for phosphorus concentrations, phosphorus loading targets, and phosphorus loading allocations, apportioned by country to ensure that Lake Ecosystem Objectives are met*."

Phosphorus targets also must be based on concentrations in the Lake's nearshore waters, as recognized by the LaMP and GLWQA of 2012 (U.S. EPA 2009b; IJC 2012). The Lake Erie LaMP's Nutrient Science Task Group includes a water quality objective of 15 ug/L for the Western Basin and notes that "*The west basin concentrations tend to be much higher than the target level of 15 ug/L"* (U.S. EPA 2009b, p. 4), a condition recently reviewed and reconfirmed by U.S. EPA (Ohio EPA 2012b). The GLWQA of 2012 includes a similar concentration as a "Substance Objective" in Annex 4. The 2009 LaMP document includes an extensive review of the phosphorus and algae issues in Lake Erie, while the Lake Erie Binational Nutrient Management Strategy (U. S. EPA 2011) continues the focus on quantitative targets and outlines priorities for nutrient management, research, monitoring and reporting actions. This Strategy is expected to be available soon, as the GLWQA of 2012 is now published. A combination of tributary load and lake modeling (Schwab et al. 2009) also might provide some indications of what level of reduction would be appropriate.

Box 11: A note on measuring phosphorus load reduction

To reduce Harmful Algal Blooms and generally restore the Lake Erie ecosystem to an acceptable level, measurement and reduction of phosphorus loads to Lake Erie are necessary. Bioavailable phosphorus, because it is the measure of the forms of phosphorus that lead to algae growth, would be a better parameter than dissolved phosphorus for setting reduction targets. However, for the tributaries of Lake Erie, dissolved phosphorus has a more complete record. Bioavailable phosphorus is not measured directly, nor is it measured routinely via indirect methods. To estimate bioavailable P we need to make several assumptions - one is the relationship between total dissolved P (not routinely measured) and dissolved reactive P (routinely measured). Heidelberg University's monitoring program (e.g., see Richards et al. 2007) has found from special studies that TDP (total dissolved phosphorus) is about 110% of DRP (dissolved reactive phosphorus), but it is not known whether this relationship is valid for all of 1975 to the present. The other assumption is about the bioavailability of particulate P and TDP; these same studies indicate that PP is about 30% bioavailable and TDP is nearly 100% bioavailable. If these assumptions are accurate and the ratios have not changed over time, then we can compute bioavailable P trends and pick a load reduction target. Such a target would be focused on the western basin. Heidelberg estimates that levels of bioavailable P are about twice what they were in the mid-1990s, so reducing tributary loads of bioavailable P by 50% would be a good initial target. A similar analysis of bioavailability of point sources and other non-tributary inputs would be needed to establish whole-lake load reduction targets from all sources. (Personal communication, R.P. Richards, Heidelberg University, August 2012).

Objective 6: *By 20XX, selected KEAs of the Lake Erie nearshore zone improve in response to reduced dissolved phosphorus.*

Specific measures for this objective reflect the goal for Nearshore that appears in the chapter on Biodiversity Conservation Targets and Viability and should include, at a minimum:

- Measure 1: Reduced algae blooms
- Measure 2: Increased dissolved oxygen
- Measure 3: Healthy and robust nearshore fish populations
- Measure 4: Healthy *Hexagenia* populations

Because of the link of phosphorus to algal blooms and other more indirect impacts on the Lake ecosystem, reductions in phosphorus loads to Lake Erie should result in improvements to several Key Ecological Attributes (KEAs), including Harmful Algal Blooms (Western and Central Basins), and nuisance *Cladophora* blooms (Eastern Basin), dissolved oxygen (Central and Western Basins), more stable fish communities and healthier nearshore fish populations such as walleye, and healthier benthic communicates, such as *Hexagenia* (mayfly) populations. The weight of evidence to support KEA measures differs considerably. Some have a long recorded history, with measures verified by field data, accepted by the scientific community and the LaMP, and used by government agencies and others to gage ecosystem protection and restoration progress (e.g., SOLEC 2011). Those which have not reached this level should be considered as "placeholder" measures until more scientifically, field-verified measures can be proposed, accepted and used. Progress toward most goals can be complicated by ongoing climate-related changes in water temperature which influences dissolved oxygen, and algal growth rates, among other factors.

There are a number of additional measures that could be used, and the SOLEC (2011) indicators that correlate with phosphorus should be tracked and considered whenever possible, as should leading alternatives. For example, a Planktonic Index of Biotic Integrity has been recommended as a broad-scale metric to monitor changes in lakes stemming from anthropogenic stressors, such as nutrient addition, in order to distinguish among levels of impairment (Kane et al. 2009).

- Measure 1: Reduced algal blooms

Algal blooms in Lake Erie have a long history of intense attention. The Great Lakes Water Quality Agreement of 1978 (GLWQA) as amended, in Annex 3 states as a goal "*Substantial reduction in the present levels of algal biomass to a level below that of a nuisance condition in Lake Erie*"[19] (GLRI 2010, p. 3), and the GLWQA of 2012 includes: (1) "Substance Objectives" for total phosphorus concentrations and Interim Phosphorus Load Targets; and (2) a "Substance Objective" "to control the growth of nuisance and toxic algae to achieve Lake Ecosystem Objectives" (IJC 2012, Annex 4). To help achieve the GLWQA goal, five "placeholder" measures of algae, including Harmful Algal Blooms and *Cladophora*, are suggested:

  - Extent of HABs as measured by NOAA satellite data
  - Concentration of HABs in lake water (such as through measurements by the University of Toledo)
  - Frequency of HAB advisories (such as measured by public beach water monitoring)
  - HAB toxin concentrations in intakes at public drinking water treatment plants
  - Areal extent and weight of standing crop of *Cladophora*

Specific objectives are not recommended at this time for the first two measures above, as the state of knowledge on what objectives should be set needs more development. Importantly, however, these measures should be recognized with "placeholders" that could lead to establishment of such objectives, where an acceptable extent and/or concentration of the blooms could be determined that would allow for a healthy ecosystem in the Lake. In the future, it might be possible to establish measures and objectives related to the data that is being collected now. NOAA's National Centers for Coastal Ocean Science and Great Lakes Environmental Research Laboratory regularly publish the "Experimental Lake Erie Harmful Algal Bloom Bulletin," which provides updates on the extent of HABs using this satellite data (NOAA 2012).

Cladophora blooms are extensively distributed wherever there is suitable habitat, especially in the Eastern Basin. The primary issue is related to the total *Cladophora* biomass. Several approaches have been used to measure *Cladophora* growth (Howell and Higgins 2011). Because coverage in suitable

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[19] The original intent of the GLWQA in 1978 referred to *Cladophora*, and while toxic blooms of cyanobacteria again have become a prevalent issue in the Western Basin, both are controlled by phosphorus dynamics.

habitat tends to be extensive, Auer et al. (2010) and Harvey Bootsma (Pers. comm. U. Wisconsin-Milwaukee, August 2012) suggest using dry weight to measure *Cladophora* blooms. Human exposure to the algae also might be considered "*A metric describing incidence of shoreline fouling based on field observation or public complaints to responsible authorities, or beach postings should be considered as a complimentary element of a Cladophora indicator*" (Howell and Higgins 2011, p.6).

The concentration of HAB biomass in the nearshore water also might be used to assess trends in water quality. The University of Toledo has collected samples to determine phytoplankton community composition in Maumee Bay and the Western Basin (Chaffin et al. 2011; Bridgeman et al. 2012). Potential indicators might include algal biomass or a proportional rating among HAB species or compared to other algae.

Two additional objectives for HABs could include:

> *By 20xx, HAB toxin measures will be reduced to the point that no HAB advisories at public beaches will be recorded and issued;*
>
> *By 20xx, HAB extent and severity will be reduced to the extent that public drinking water treatment plants do not incur additional treatment costs related to HABs in the source water*

Because the State of Ohio has established a formal HAB advisory program (Ohio Harmful Algal Bloom Response Strategy http://ohioalgaeinfo.com/), based on algal toxin levels measured at beaches, such information could be used as one measure of HAB impacts. However, this is only a measure of toxins produced by HABs at a limited number of beach sites, does not address the open water concentrations, is not yet consistent, and is only a very indirect measure of ecosystem and biodiversity conditions and effects. A second, similar measure could be based on the extent that drinking water treatment plants incur additional treatment costs related to algal blooms (Pers. comm., Trinka Mount, Ohio EPA, August 2012), although this has similar limitations. The advantage of using such measures is that the data is regularly collected because of the strong interest in protecting human health.

The Great Lakes Restoration Action Plan includes a comparable measure of progress for nuisance algae (which in this reference includes both HABs and *Cladophora*), "*Annual number of days U.S. Great Lakes beaches are closed or posted due to nuisance algae*" (GLRI 2010, p. 29).

- Measure 2: Adequate dissolved oxygen

Excessive nutrient loading supports algal blooms, which lead to and are a primary cause of low oxygen levels. The extent of inadequate dissolved oxygen levels in Lake Erie could be used as a key measure for the nearshore waters and beyond. While the Nearshore Zone's shallow depths allow wind mixing, generally preventing thermal stratification, some hypoxia has been found in the Nearshore Zone of Lake Erie, such as near the Western Basin's Lake Erie islands. The nearshore area of the Western Basin has not been the main focus of hypoxia measures and documenting dissolved oxygen data are not routinely collected. Much more extensive and better known is the hypoxia problem in the offshore waters of the Central Basin (Arend et al. 2011). Krieger and Bur (2009) found that dissolved oxygen depletion had a "*strong impact on the ecology of the nearshore and westernmost regions of the* [Central] *basin*." (p. 3) The nutrients and algae from the Western Basin nearshore are the primary contributors to the Central Basin problem and are probably augmented by other sources, such as in situ "legacy" phosphorus in the Central Basin sediments. Dissolved oxygen concentration measurement would help determine if reductions of phosphorus and algae are having the desired effects.

A recommended objective for dissolved oxygen is:

By 2030, the frequency of nearshore hypoxia and anoxia events will be reduced.

Krieger and Bur (2009) measured dissolved oxygen in the nearshore zone of the Central Basin. They defined hypoxia as a dissolved oxygen concentration between 1.0 mg/L and 2.0 mg/L, and anoxia as a concentration below 1.0 mg/L. The Great Lakes Fishery Commission (2011, p. 29) states "*Dissolved oxygen less than 4 mg/L is deemed stressful to fish and other aquatic biota.*" Krieger and Bur (p.1) that anoxia "*is sufficiently widespread and persistent to account for the degraded benthic invertebrate communities that have characterized shallow regions of the basin for decades*," and that "*specific criteria upon which a hypoxia metric would be scored annually would need to be developed by collaborating agencies*." Also, as some oxygen depletion is natural, determinations will have to be made as to achievable goals to recognize that not all hypoxia and anoxia is human activity-induced.

- Measure 3: Healthy and robust nearshore fish populations

Indirect effects of excessive nutrient loads on fish populations range from effects related to hypoxia, physiology, spatial distributions, predator-prey relationships, and these can collectively result in effects on population dynamics, trophic interactions and energy flow, and species richness. These effects differ among species and life stages (Arend et al. 2011). A running average could be used for this measure, such as over three years for total native intolerant fish species richness in annual bottom trawl surveys. Ludsin et al. (2001) tracked the number of tolerant and intolerant fish species of eutrophication (i.e., anoxia or turbidity) captured in Lake Erie's western and Central Basins and showed the number of intolerant species declined with increasing eutrophication. Walleye (GLFC 2012b) and yellow perch (GLFC 2012c) are likely species candidates for monitoring, already extensively tracked by the Great Lakes Fishery Commission, and are included in the Nearshore indicators in Appendix E.

- Measure 4: Healthy Hexagenia populations

"*Hexagenia can be a useful indicator of lake quality where its distribution and abundance are limited by anthropogenic causes*" (Krieger et al. 2007, p. 20), and the status of the western and Central Basins have been a focus of study (Krieger 2004). As a dominant benthic organism in the Nearshore Zone, the mean density of *Hexagenia* in fine sediments, using a three year average, could be used as a measure of lake health. *Hexagenia* are included in the Nearshore indicators in Appendix E.

Related strategies and initiatives

Many agencies and organizations around the lake are striving to address this issue, as exemplified by nutrient reports and management strategies being produced by the Lake Erie LaMP and the states and

Ontario, as well as efforts to implement and improve agricultural best management practices in watersheds of Canada and in the US. Some examples are listed below.

- International Joint Commission, Great Lakes Water Quality Agreement, 2009–2011 Priority Cycle Report on A Nearshore Framework, http://meeting.ijc.org/sites/default/files/flash-book/nearshore.pdf
- International Joint Commission, Great Lakes Water Quality Agreement, IJC Work Group Report on Harmful/Nuisance Algae http://meeting.ijc.org/sites/default/files/flash-book/algae.pdf
- IJC WQB 2012-2013 Priority Cycle
- IJC Lake Erie Ecosystem Priority http://ijc.org/rel/news/2012/120730_e.htm
- Great Lakes Restoration Initiative Action Plan (2010) http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf
- Lake Erie LaMP, Lake Erie Binational Nutrient Management Strategy (Lake Erie LaMP. 2011, draft only); also see "Status of Nutrients in the Lake Erie Basin" technical report, http://epa.gov/greatlakes/lakeerie/erie_nutrient_2010.pdf.
- LaMP, Lake Erie Nutrient Science Task Group: Status of Nutrients in the Lake Erie Basin (2009)
- Great Lakes Commission. Priorities for Reducing Phosphorus Loadings and Abating Algal Blooms in the Great Lakes – St. Lawrence Basin. http://www.glc.org/announce/12/pdf/FINAL_PTaskForceReport_Sept2012.pdf
- Great Lakes Commission. Nutrient Management: A Summary of State and Provincial Programs in the Great Lakes - St. Lawrence River Region. http://www.glc.org/announce/12/pdf/FINAL_NutrientManagement_Sept2012.pdf
- State/Provincial and Federal Agriculture Departments promoting and implementing best management practices in key watersheds, including the Maumee, Raisin, Thames, and others.
- Ontario Nutrient Management Act http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_02n04_e.htm
- SERA – 17 http://www.sera17.ext.vt.edu/Meetings/greatlakespforum/agenda.shtml
- Ohio Lake Erie Phosphorus Task Force Final Report (Phase I, 2010) http://www.epa.ohio.gov/portals/35/lakeerie/ptaskforce/Task_Force_Final_Report_April_2010.pdf),and Phase II (planned)
- TheU.S. Army Corps of Engineers (USACE) - Great Lakes Tributary Modeling Program www.glc.org/tributary
- Ohio Nutrient Reduction Strategy Framework/Directors' Agriculture Nutrient Work Group ReportLake Erie Millennium Network (LEMN) http://www.lemn.org/
- Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA)
- Great Lakes Nutrient Initiative (Environment Canada) http://www.ec.gc.ca/default.asp?lang=En&n=56D4043B-1&news=7D6BB6E6-F67C-4477-AFB7-19E6310A8E15
- Drainage Act (Ontario – Ministry of Agriculture, Food and Rural Affairs)
- Canada-Ontario Environmental Farm Plan
- Canada-Ontario Farm Stewardship Program

- Great Lakes Protection Act and associated Strategy (newly proposed by the Ontario government – Ministry of the Environment) (not yet passed in the Ontario legislature)
- Grand River (Ontario) Water Management Plan http://www.grandriver.ca/
- Conservation Authorities' (Ontario) watershed and/or shoreline management plans
- Conservation Effects Assessment Program (USDA-NRCS)
- State/Provincial and Federal Agriculture Departments and Conservation Authorities (Ontario) or Districts (U.S.) promoting best management practices in key watersheds, including the Maumee, Raisin, Thames, and others.
- The Nature Conservancy's Great Lakes Project, Agriculture-Altered Hydrology strategic priority

Likely participating agencies and organizations

Federal, state/provincial, watershed (e.g. Ontario Conservation Authorities) and local agricultural and conservation agencies, agricultural trade associations and NGOs.

6.2.3. Strategy 2: Promote surface and subsurface drainage options, policies and programs that reduce nutrient losses and delivery

This strategy focuses on the role of surface and subsurface drainage in the delivery of nutrients and sediment to Lake Erie. Drainage was recognized as a key, separate issue but not addressed in the December strategy workshop due to time constraints; the following strategy was developed in a follow-up workshop on April 12, 2012, at Side Cut Metro Park, Maumee, Ohio. The strategy and actions considers the drainage routes, methods and activity that affects hydrology, including upland management and crop fields, stream channels (e.g., channelization), surface drainage systems (e.g., ditches), subsurface drainage (e.g., tile) systems, and other watercourses and features (e.g., grass waterways, floodplains, wetlands).

Many farming practices, including conservation tillage, depend on drainage to produce profitable crop yields. The Lake Erie watershed, especially the Western Basin, is one of the more extensively drained areas in North America. In addition to drainage's direct alteration of stream and wetland habitat,

> "*Indirect effects include water quality and habitat impacts of sediment, phosphorus, nitrogen and other contaminants in agricultural runoff, as well as hydrologic alteration in the form of altered volume and timing of runoff. Alteration of flow regimes in turn drives a complex of interrelated changes in stream morphology, instream and riparian habitats, nutrient cycles, and biota"* (Blann et al. 2009, p. 910-911).

Surface drainage, i.e., ditches and channelized streams, can serve as routes for transport of pollutants such as sediment, nitrogen and phosphorus. In northwest Ohio, research suggests that "*biological processing is not very effective in drainage ditches, or at least that it is not efficient enough to keep up with new inputs along the length of the ditch*" (Richards et al. 2008, p. 4). The subsurface drainage (usually plastic tile) is the other known route, where "*significant P export in either dissolved or particulate forms occurs via subsurface drainage under conditions associated with leaching or elevated sediment/runoff delivery to subsurface drains"* (Blann et al. 2009, p. 947). Reid et al. (2012) have

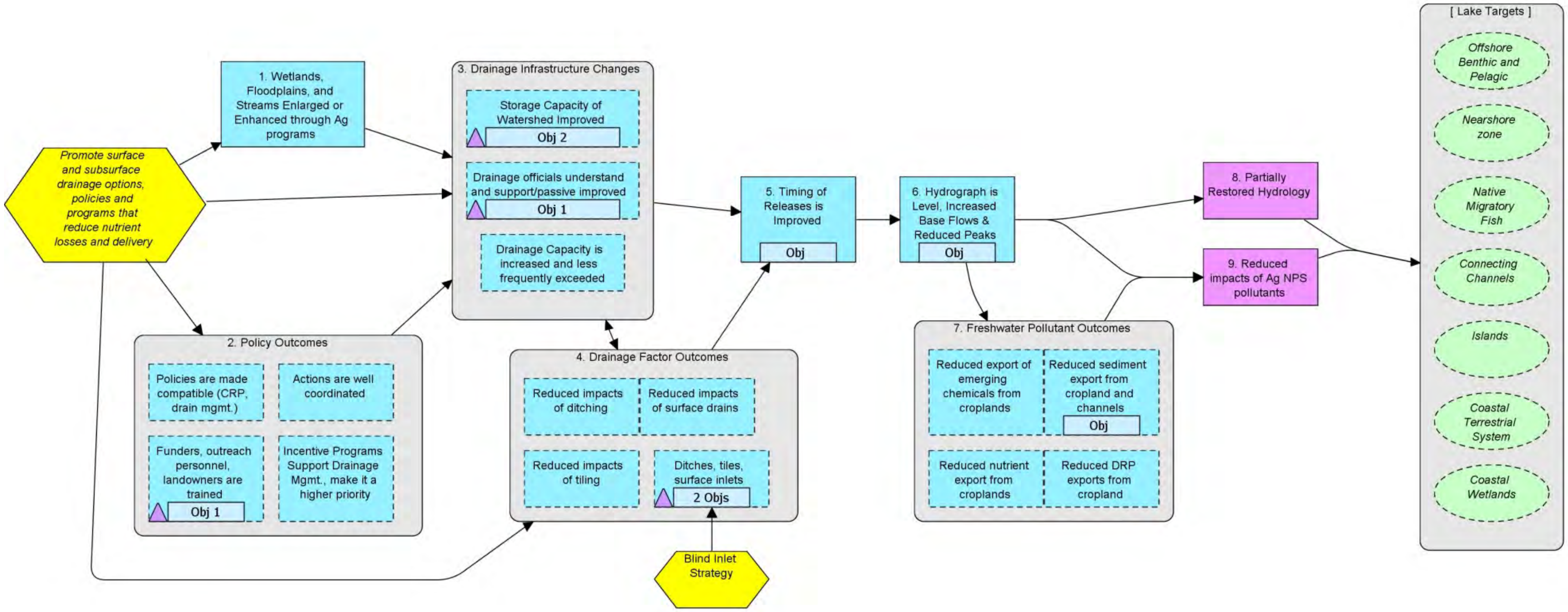

Figure 32: Results chain for the strategy to promote surface and subsurface drainage options, policies and programs that reduce nutrient losses and delivery.

recently proposed a P index to account for these pathways in a P index for Ontario. The Ohio Lake Erie Phosphorus Task Force (Ohio EPA 2010, p. 56) stated that "*with subsurface drainage more of the incident precipitation moves into and through the soil profile and out through the drainage system, potentially exporting DRP encountered along this pathway*." In addition, the release of water from drains into small surface waters also can promote downstream flooding, which is of growing concern given the likelihood of increases in peak storm intensities as the climate continues to change.

The amount that drainage contributes to both pollutant transport and the reduction of such losses depends on a number of factors, including soil conditions. While pollutant losses and hydrologic alteration related to drainage have been well studied, there is a continuing need to learn much more to better address drainage problems related to reducing nutrient losses (Ohio EPA 2010). Given what is known, it seems unlikely that nutrient management alone, without efforts to address problems exacerbated by drainage practices, will be adequate for improving water quality. Strock et al. (2010; p. 135A) identified "*a number of practices that could be used to reduce the off-site transport of pollutants in drainage water—drainage system design, controlled drainage, drainage ditches, water storage, buffers and vegetative filter strips, side-inlet controls, reactive barriers, and agronomic management.*"

The science of drainage management needs to be more fully developed in order to set policies and programs to reduce nutrient losses and delivery. Significant work is needed to design, develop and implement in-field applicability and BMP effectiveness in reducing phosphorus export from drainage.

While a number of practices have been identified, and this strategy encourages implementation of environmentally-friendly drainage practices, much more needs to be known about what practices to implement. Importantly, we need research to develop and test many more new practices. Further, not enough is known about how effective these changes in drainage practices can be, and how much they reduce pollutants and modify hydrology relative to quantified objectives. While some techniques to reduce losses and hydrologic impacts from surface and subsurface drainage have been around for the past decade (e.g., channel designs, drainage water management), there is still a great need to develop and invest in new ideas and research the effectiveness of those new BMPs and those that have been used for years. There is a need for development, evaluation and review of these and other techniques. While we know that drainage is a significant contributor to pollutant losses and hydrology, we need to know much more about how to effectively target, develop and refine drainage BMPs to reduce losses accordingly.

Nutrient management needs to concentrate on prevention of pollution from crop fields, and on better control and treatment BMPs related to drainage, both for quality and quantity. For surface drainage, riparian management, floodplains and wetlands commonly have been recommended and used as BMPs to control and reduce losses (e.g., OMAFRA 2011). "*A slate of recent studies has demonstrated that subsurface drains have the potential to be significant conduits of sediment and associated agrochemicals in a wide variety of environments*" (Blann et al. 2009, p. 930). The Ohio Lake Erie Phosphorus Task Force Report (Ohio EPA 2010) states "*There are several BMPs (e.g., drainage control structures, cover crops, wetlands, etc.) available to reduce phosphorus loading to streams from tile drainage systems"* (p. 57). Tan and Zhang (2011) found that tile drainage played a predominant role in soil P loss, and recommended that the practice of controlled drainage could be a beneficial management practice to reduce phosphorus loss in southern Ontario.

Research continues to evaluate the effectiveness and conditions under which these technologies may be used. Research is needed to better determine the results of combinations of fertilizer management, cropping systems, and drainage, and to determine how much impact fertilizer and manure application rates and timing, cropping systems, other management practices and conservation BMPs have on the amount of nutrient loss from drainage flow. Research also is needed on how to achieve the most effective control and treatment of pollutants once they have entered the drainage system. In addition, because drainage that increases productivity can help to reduce nutrient losses, there are trade-offs between drained and non-drained conditions, both in terms of crop productivity and nutrient balance due to higher yields, and net nutrient losses. Proposed solutions to nutrient losses from drainage should not lead to other inadvertent losses in crop yields or to increases in runoff. Examining these tradeoffs would be useful to help inform what and how much of a BMP would be necessary, or help inform new strategies and BMPs to address the nutrient issues.

In summary, drainage needs attention given:

> (1) The relatively high concentrations of nutrients and sediment in drainage leaving the fields; and
>
> (2) The hydrology impacts such as flashiness and channel scour, leading to more nutrients and sediment due to downstream impacts on ditches and streams.

Finally,

> (3) Research is needed to better determine the extent of the problem and effectiveness of avoidance, treatment and control measures within the drainage system.
>
> (4) Incentives to improve the environmental effects of drainage need to be developed so that programs are implemented at a scale that is commensurate with the problem.

Strategic actions

Implementing this strategy will require a number of actions that fall into several categories.

Policy actions:

Government agencies should (1) use existing programs to provide for environmentally-friendly drainage improvements; and (2) strengthen and revise existing policies to allow greater use and flexibility.

Competing policies need to be made compatible. Specifically, agencies should review and determine agricultural program changes that would make nutrient loss reduction related to drainage most effective.

Several program options exist for creating or enhancing financial incentives, or might be in need of review and revision, such as through the USDA Farm Bill programs, GLRI, the Great Lakes Protection

Fund, water quality trading under the Clean Water Act, or in Canada through the Environmental Farm Plan administered by Ontario Soil and Crop Improvement Association or the Rural Water Quality Programs offered by Conservation Authorities.

Key players in these actions include: U.S. Department of Agriculture, Agriculture and Agri-Food Canada, state/provincial agencies and legislatures, agricultural organizations (Farm Bureau, Ontario Soil and Crop Improvement Association and Ontario Federation of Agriculture, etc.), Soil and Water Conservation Districts, Conservation Authorities, NGOs, International Joint Commission, U.S. EPA, Environment Canada, and other conservation authorities.

Education actions:

Agencies and partners should develop and implement education and awareness programs emphasizing nutrient and sediment losses through drainage, targeting the drainage community (drainage officials, the drainage industry, farmers, landowners, and state, provincial and federal governments).

Some of this education is already occurring, as exemplified by outreach from The Ohio State University (The Ohio State University Extension 2012). Others who are or could be engaged in this educational program include Soil and Water Conservation Districts, Conservation Authorities, Cooperative Extension Service programs, universities, USDA Agricultural Research Service and Natural Resource Conservation Service, Agriculture and Agri-Food Canada, Ontario Ministry of Agriculture, Food and Rural Affairs, NGOs, and the drainage community.

Restoration actions:

Agencies and partners should pursue environmentally-friendly drainage-related actions (e.g., Wetland Drain Restoration practiced in Ontario, Wetland Drain and Buffer Restoration projects in the Long Point Region) and BMPs including: watershed restoration through green infrastructure practices; improving water storage capacity; on-farm/in-field modifications (crop management for soil tilth and health; measures affecting the amount and timing of water flow) and non-crop modifications (wetland, floodplain and in-stream practices, for example).

These are achieved through agricultural programs, such as the Farm Bill programs and Canada-Ontario Environmental Farm Plan, and affect drainage hydrology and nutrient losses. Key players in these actions include landowners, producers/farmers, watershed councils, local drainage officials, Soil and Water Conservation Districts and Conservation Authorities, U.S. EPA, U.S. Army Corps of Engineers, State/Provincial Departments of Agriculture, NGOs, private consulting firms/engineering/crop consultants/land improvement contractors, the Ontario Soil and Crop Improvement Association, USDA Natural Resources Conservation Service and Agriculture and Agri-Food Canada.

Science actions:

Science actions needed include those related to: determining priority areas and conducting research on the effectiveness of drainage practices; and continuing research into controlled drainage and sub-irrigation as a means of effectiveness for reducing P exports to watercourses and the Great Lakes.

To focus on areas of greatest potential reduction of nutrient and sediment losses, agencies and partners should define priority watersheds for both the nutrient management (See Strategy 1) and for environmentally-friendly drainage; define the biggest contributing areas and activities and model potential benefits of taking action. Much of this effort could be combined with Strategy 1 efforts to determine priority watersheds.

Agencies and partners should establish a baseline by mapping current drainage practices, hydrology and topography. For example, in Ontario all newly installed tile drainage tile is required to be geo-referenced. Previously installed tile is being geo-referenced as time and resources permit.

Agencies and partners should conduct research to better determine the extent of the problem and effectiveness of avoidance, treatment and control measures within the drainage system. This should address knowledge and information gaps including: understanding the tradeoffs related to new drainage alternatives and nutrient losses, and between conservation tillage and reduced dissolved phosphorus (e.g., such as related to channeling/preferential flows that are associated with earthworms in conservation tillage soils); understanding dissolved vs. particulate phosphorus movement; mechanisms and processes; and articulate how these affect dissolved phosphorus and nitrate. Research also is needed to evaluate the role of subsurface drainage on the resiliency of crops during heatwaves/droughts that are projected under climate change.

Key players Likely participating agencies include state/provincial water quality agencies, USGS, Great Lakes Commission, NRCS, Agriculture and Agri-Food Canada, OMAFRA, academia, NGOs, U.S. ACOE, Soil and Water Conservation Districts and Conservation Authorities, and LaMP participants.

Results, objectives and measures

Through implementing policy, education, restoration and science, as described above, this strategy will lead to both an increase in natural features that improve hydrology and changes in policies that together will allow for improvements in drainage practices and infrastructure (Figure 18). Improved practices and infrastructure components will lead to improvements in drainage factors and timing of water releases, which will eventually reduce the volume and rate of runoff, reduce flashiness as shown by the hydrograph and cause other hydrologic improvements. Improved hydrology will reduce pollutant exports from fields and streams, as well as relief from the stress of altered hydrology. Biodiversity conservation targets, especially the Nearshore Zone, will benefit from a reduction of these threats, though the amount of benefit is difficult to estimate.

Result 1. Wetlands, floodplains, streams enlarged or enhanced, and improved function

Natural wetlands, streams, and riparian areas will be restored, enlarged or enhanced in quality. These are achieved through agricultural programs and affect drainage impacts and nutrient losses.

Result 2. Policy outcomes

There are four results related to improved policies:

2a. Government agencies (1) use existing programs to provide for environmentally-friendly drainage improvements; and (2) strengthen and revise existing policies to allow greater use and flexibility. Competing policies are made compatible. Barriers to funding drainage-related conservation measures are removed. Policies that may have conflicting components, such as the Conservation Reserve Program (CRP) and drainage management, are reconciled.

2b. Actions are well coordinated. Agencies and organizations coordinate to make greater progress and reduce inefficiency.

2c. Funders, outreach personnel and landowners are trained to recognize drainage-related opportunities resulting in environmental improvements. This is a key result, with one associated objective:

Objective 1. By 2016, 100% of all local, state, federal and provincial personnel who influence drainage programs have received training in water quality and nutrients.

2d. Incentive programs support environmentally beneficial management of drainage and make it a higher priority.

Result 3. Drainage infrastructure changes

This result has three components:

3a. Hydrologic storage capacity of watersheds is improved. There is one associated objective:

Objective 2: By 20xx, X acres of existing agricultural lands have new or retrofitted drainage water management systems (i.e., modifying any built infrastructure; largely subsurface; NRCS Practice 554, Drainage Water Management (NRCS 2012)) in place in priority watersheds.

Measure 1: Number of acres of agricultural lands that have new or retrofitted drainage water management systems.

3b. Drainage officials understand and support improved drainage water management. Objective 1, as stated above, also applies to this result.

3c. Drainage capacity is increased and less frequently exceeded.

Regarding "drainage capacity," participants proposed that, if more "upstream" management of water was implemented, then the capacity of the drainage system would be less likely to be exceeded because there would be more water management in the fields, wetlands and other water-holding features, and in the tile system, than further downstream in the receiving channels.

Result 4. Drainage factor outcomes.

This group includes four outcomes:

4a. Reduced impacts of ditching.

4b. Reduced impacts of surface drains.

4c. Reduced impacts of tiling.

4d. Ditches, tiles, surface inlets designed with reduced hydrologic impacts in mind, such as through improved channel designs, surface inlet restrictions and controlled drainage management.

Agencies and partners will need to conduct research on the effectiveness of these drainage practices.

There are two objectives associated with this result, one of which is Objective 2, stated above. The other is:

Objective 3: *By 2025, Reduce by 50% the number of in-field surface inlets with no restriction on inflow and reexamine new technologies which limit pollutant transport from sub-surface drainage systems..* This objective will require actions specific to blind inlets (or any design that restricts flow and limits pollutant transport from the surface to the subsurface drainage system) and also will need to differentiate between surface inlet and macropore flow to tile drains.

Result 5. Timing of releases is improved ; hydrograph is less flashy with increased base flows & reduced peaks

The point here is to reduce the influence of flow and flashiness created by drainage on delivery of sediment and nutrients to the streams and consequently Lake Erie. This result has one associated objective:

Objective 4: By 2025, reduce the energy of channel eroding flows in the Lake Erie basin by 25%. Potential measures include:

- Measure 1: Duration of insufficient baseflows during dry summer months
- Measure 2: Determine differences in resulting flow hydrographs between conventional and environmentally-friendly drainage practices.

Agencies and partners will need to conduct research, including modeling and monitoring, on the effectiveness of drainage practices, including these and other flow measurements.

Result 6. Freshwater pollutant outcomes

Nutrient losses through the drainage system need to be addressed along with nutrient management. Programs and projects must consider that effective reductions of nutrient losses will mean tailoring the implementation of 4Rs and all BMPs to the conditions in artificially drained fields. There are four outcomes related to freshwater pollutants:

7a. Reduced nutrient export from croplands.

7b. Reduced DRP exports from croplands. This result is related to the above result, but focuses on the most critical nutrient—dissolved reactive phosphorus.

7c. Reduced sediment export from cropland and channels. This result has one associated objective:

Objective 5: *By 2025, average annual sediment loads reduced by X% in highest priority areas. In 2015 re-examine the reduction of annual sediment loads reduced once priority areas are established/monitored then set a target amount to achieved by 2025.*

These results will be determined through the research referred to above and the ambient monitoring conducted by agencies and partners.) Note the connection to Strategy 1 - where much of this objective also would be expected to be achieved - above and also note the suspended sediment indicator.

7d. Reduced export of emerging chemicals from croplands.

Result 8. Partially restored hydrology

Agencies and partners will need to conduct research on the effectiveness of drainage practices, including these and other flow measurements, on the hydrologic results in streams and ditches.

Result 9. Reduced impacts of agricultural NPS pollutants

These results will be determined through the research referred to above and the ambient monitoring conducted by agencies and partners.

Priority or opportunity areas for implementation

Strategy 1, Objective 1, above, recommends identification of areas within priority watersheds are identified for focus of farm-based nutrient management efforts; drainage strategies and actions should be coordinated with this effort.

Related strategies and initiatives

Drainage strategies must be coordinated with Strategy 1 above, which focuses on targeting and intensifying nutrient management BMPs, including the 4Rs, to reduce phosphorus loadings Many agencies and organizations around the lake are striving to address this issue, as exemplified by nutrient reports and management strategies being produced by the Lake Erie LaMP, the states and Ontario, as well as efforts to implement and improve agricultural best management practices in watersheds of Canada and the US. Some examples are listed under Strategy 1, above. To focus on areas of greatest potential reduction of nutrient and sediment losses, agencies and partners should define priority watersheds for both the nutrient management (examples are listed in Strategy 1) and for environmentally-friendly drainage.

Likely participating agencies and organizations

Federal, state, provincial and local agricultural and conservation agencies, academia, agricultural trade associations and NGOs.

6.3. Preventing and reducing the impact of invasive species

Invasive species are plants or animals that are non-native (or alien) to an ecosystem, and whose introduction is likely to cause economic, human health, or environmental damage. During the past two centuries, invasive species have significantly changed the Great Lakes ecosystem including the introduction of common carp (*Cyprinus carpio*), dreissenid mussels (*Dreissena polymorpha, D. bugensis)*, round goby and European common reed.

We have identified key strategies to address both terrestrial and aquatic invasive species. Invasive species were divided into these two groups since aquatic and terrestrial invasive species impact different targets, and generally have different strategies, recognizing there is overlap between some strategies (such as outreach) and there may be opportunities to combine some actions.

The top priority terrestrial strategies are: 1) Assemble key regional partners to create a coordinated action plan for Common Reed and other priority terrestrial invasive species by 2013; 2) Coordinate policies and regulation of Common Reed in Canada and the U.S.; 3) Improve coordination of early detection and rapid response of Common Reed; and 4) Enhance coordination of outreach and marketing. The aquatic strategies include 1) Develop a coordinated framework for aquatic invasive species control/ management for Lake Erie by the end of 2013; 2) Build political support for policies and regulations that enable more effective control and management of aquatic invasive species; 3) Improve coordination of early detection and rapid response of aquatic invasive species; and 4) Demonstrate and quantify results of ecological restoration. Most of the lower priority strategies identified from the workshop have been incorporated into these strategies as strategic actions.

6.3.1. Priority strategies

The conceptual models were initially divided between aquatic and terrestrial invasive species. These were then further divided to recognize that there are distinct drivers and potential strategies for existing invasive species and future/ potential invasive species. Most of the focus for terrestrial invasive species was on Common Reed. Existing aquatic invasive species include Dreissinid mussels and round gobies. The main potential aquatic invasive species threat that does not currently occur in Lake Erie is Asian carp (although individuals have been captured and DNA recorded), specifically bighead carp and silver carp. Strategies were not developed for Asian carp since there are basin-wide, complementary strategies being developed, including the Asian Carp Control Strategy Framework (The Asian Carp Regional Coordinating Committee 2012).

In the workshop, 17 strategies were identified for terrestrial invasive species and 19 strategies were identified for aquatic invasive species. Experts voted on the priority strategies that they believed would be the most effective to reduce invasive species and practical to implement. Following the workshop several of the strategies were then integrated into the priority strategies as strategic actions. For both aquatic and terrestrial species the top strategies included improving coordination of policies, actions and reporting. Table 16 lists the potential and priority strategies that were identified for terrestrial invasive species.

Table 16: Potential strategies for reducing the impacts from Terrestrial Invasive Species. Tier 1 strategies were considered of highest priority and were selected for more detailed strategy development. Tier 2 strategies are also important to address this threat.

Strategies	Priority
Assemble key regional partners to create a coordinated action plan for Common Reed and other priority terrestrial invasive species by 2013.	Tier 1
Coordinate regulations related to Common Reed in Canada and the U.S.	Tier 1
Improve coordination of early detection and rapid response of Common Reed.	Tier 1
Enhance coordination of outreach and marketing.	Tier 1
Build a clearing house of success stories	Tier 2
Clearly map distribution of major invasives to supported targeted approaches and coordination	Tier 2
Coordinate restoration efforts with appropriate environmental agencies to reduce impacts of habitat management	Tier 2
Coordinated risk assessment for potential invasive species	Tier 2l
Develop adaptive restoration BMPs	Tier 2
Enhanced legislation and regulatory tools to prevent entry of new species	Tier 2
Form CWMA for areas of Lake Erie	Tier 2
Improve prediction of where land/water interface will be under different lake levels and improve accuracy of lake level models	Tier 2
Improved coordination with landowners	Tier 2
Monitoring and follow-up of action sites	Tier 2
Prevention of invasive species in key areas (e.g. islands)	Tier 2
Reduce human dispersal	Tier 2
Restoration of coastal habitats	Tier 2
Set landscape priorities	Tier 2

Table 17: Potential strategies for reducing the impacts from Aquatic Invasive Species. Tier 1 strategies were considered of highest priority and were selected for more detailed strategy development. Tier 2 strategies are also important to address this threat

Strategies	Priority
Develop a coordinated framework for aquatic invasive species control/management for Lake Erie by the end of 2013	Tier 1
Build political support for legislation, regulations, and policies that enable more effective control and management of aquatic invasive species.	Tier 1
Complete a cost-benefit analysis for current aquatic invasive species	Tier 1
Coordinate state/provincial/federal ballast water legislation	Tier 1
Coordinated risk assessment	Tier 1
Demonstrate and quantify results of ecological restoration	Tier 1
Improve coordination of surveillance and monitoring to enhance early detection and rapid response.	Tier 1
Conduct risk assessments	Tier 2
Coordinated outreach based on social science marketing	Tier 2
Education and marketing at key sites	Tier 2
Fund and form a basin-wide rapid response team	Tier 2
Improve regulatory policy	Tier 2
Improve screening policy regulations	Tier 2
Increase outreach	Tier 2
Increased enforcement of existing baitfish laws	Tier 2
Maintain refuges for native mussels in diked wetland	Tier 2
Provide economic incentive for compliance	Tier 2
Quantify economic impacts	Tier 2
Restore ecological separations	Tier 2
Sustained investment and funding	Tier 2

It was recognized that for many of these priority strategies, there are many existing programs and actions (such as developing coordinated risk assessments), and the group focused on strategies that are currently not being implemented.

For both aquatic and terrestrial invasive species, the group identified that strategies related to improved coordination were the top strategy. For terrestrial invasive species, the development of a coordinated action plan was identified as a key strategy, since it would enable and support many of the other strategies and help to provide context for existing programs and strategies. For aquatic invasive species, the development of a control/management framework and a coordinated risk assessment were identified as key strategies to help mitigate the barrier of lack of political support and lack of key policies.

6.3.2. Terrestrial Strategy 1: Assemble key regional partners to create a coordinated action plan for Common Reed and other priority terrestrial invasive species by 2013

Strategic actions

- Complete a risk assessment on other terrestrial invasive plants for the Lake Erie coast.
- Develop a "watch-list" of priority coastal invasive species including Information on their distribution, and update this information every five years. Incorporate this information into a five-year "State of Lake Erie Biodiversity" report. Include updates on priority areas for control, and priority areas for early detection and eradication.
- Map current distribution of Common Reed.
- Set landscape priorities
- Engage key partners in coordinated planning efforts and ensure they are and invested in the results.
- Build on existing initiatives including the Ontario Phragmites Working Group and the Great Lakes Phragmites Collaborative.
- Form a cooperative weed management areas CWMA for areas of Lake Erie
- Coordinate restoration efforts of coastal habitats with appropriate environmental agencies to reduce impacts of habitat management.
- Prevention of invasive species in key areas (e.g. islands)
- Monitoring and follow-up of action sites

Results, objectives and measures

Objective 1: *By 2015 reduce the total area of Common Reed along the Lake Erie coast by 5%.*

- Measure 1: area of Common Reed.
- Measure 2: number of acres under management for invasive species control

Related strategies and initiatives

- Great Lakes Restoration Initiative Action Plan, Invasive Species Goal 5 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf
- Conservation Authorities' (Ontario) watershed and/or shoreline management plans
- Several agencies are already managing Common Reed. This includes The Nature Conservancy and U.S. Fish and Wildlife Service in the Ottawa National Wildlife Refuge, Long Point Region Conservation Authority in Long Point (Lee Brown Marsh) and Nature Conservancy of Canada on Pelee Island.

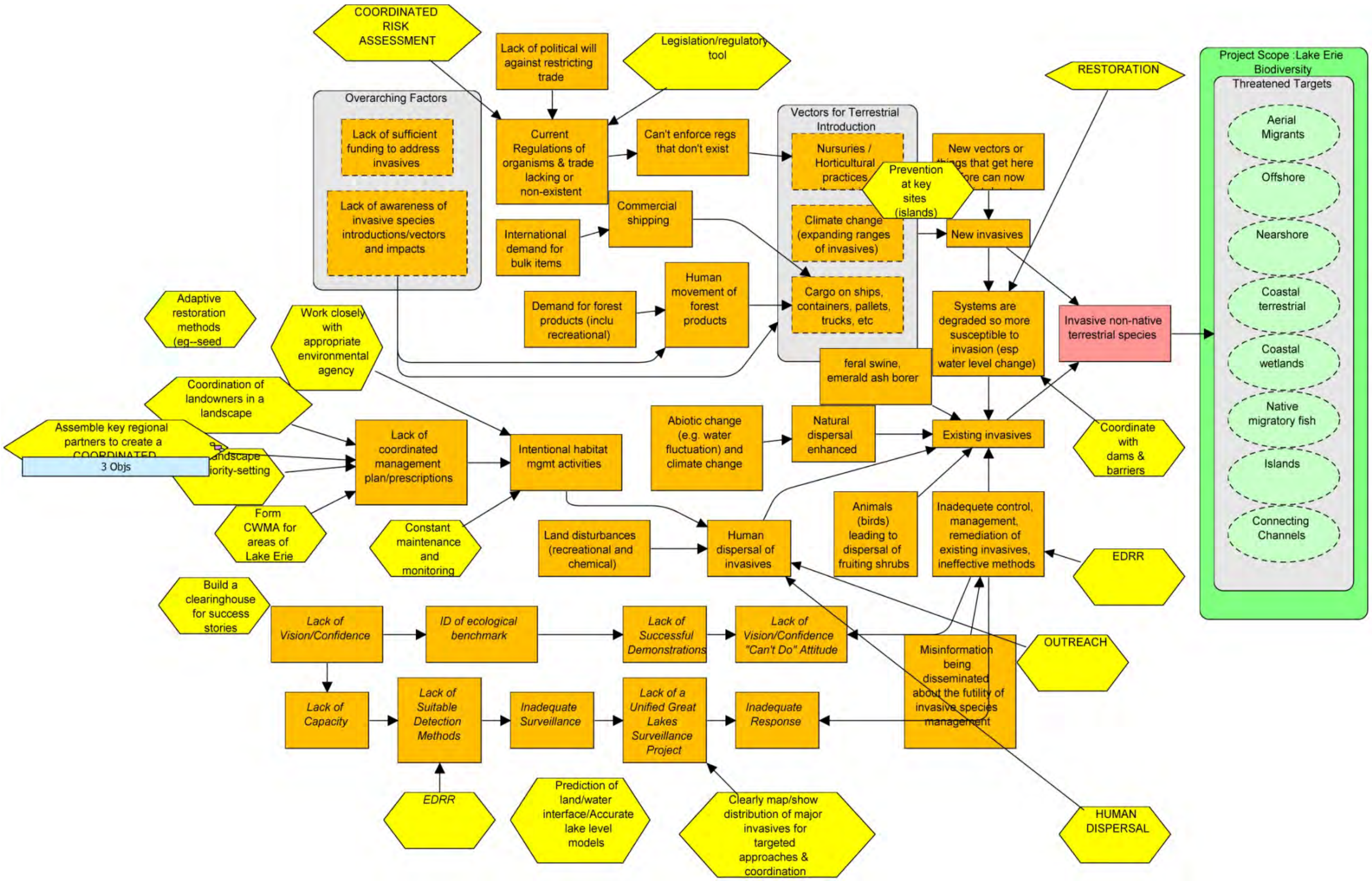

Figure 33: Conceptual model of terrestrial invasive species in Lake Erie.

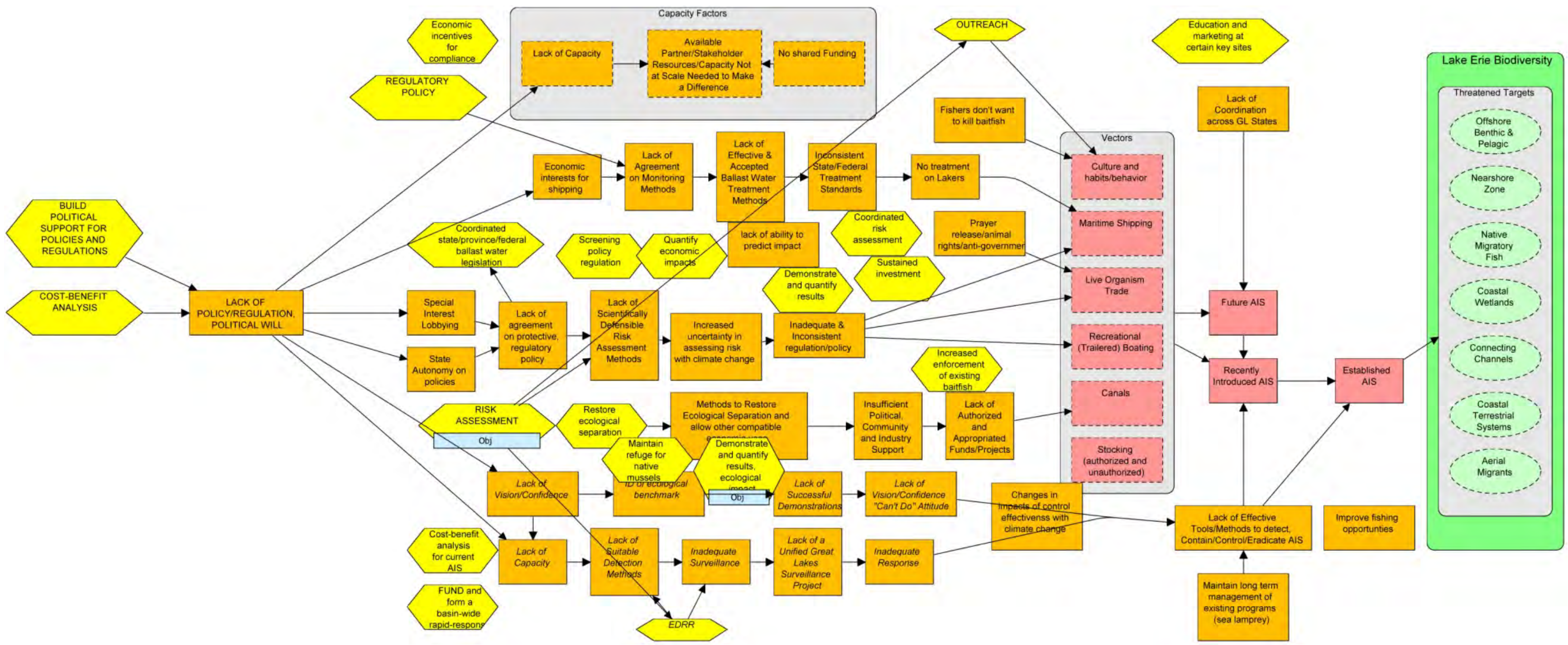

Figure 34: Conceptual model of aquatic invasive species in Lake Erie.

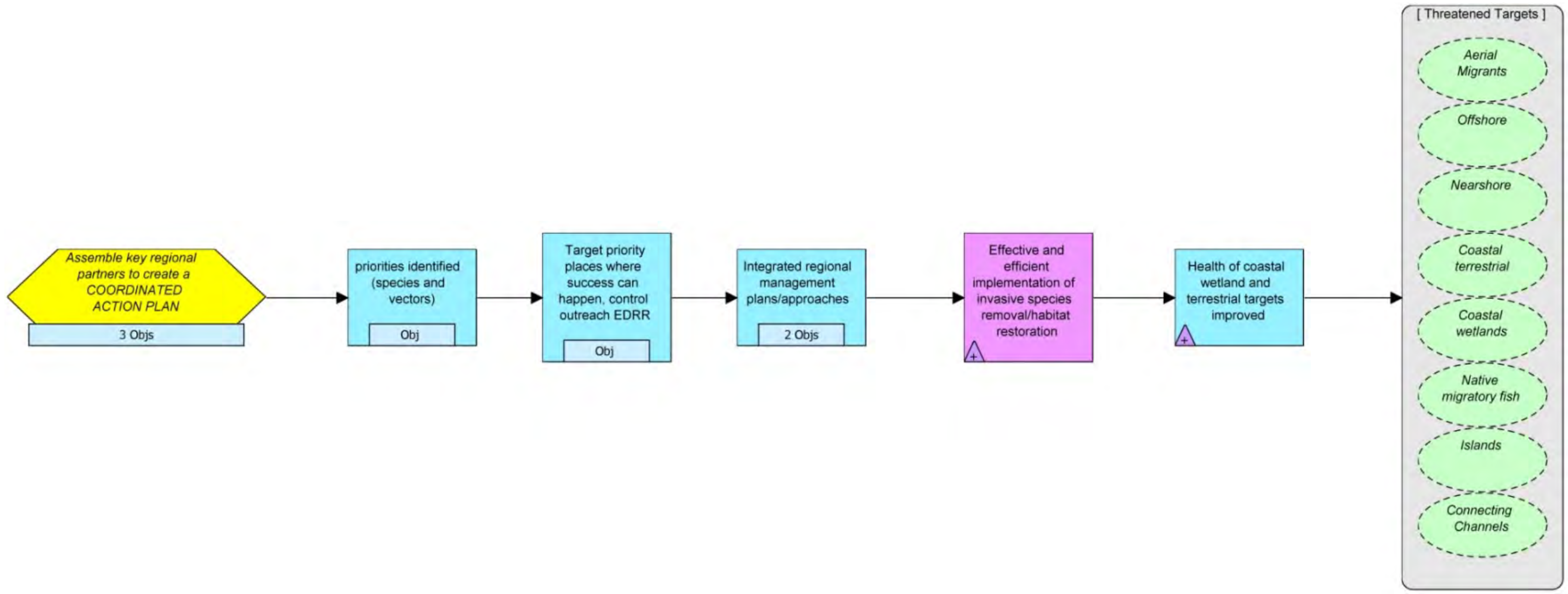

Figure 35: Results chain for a coordinated action plan for abating invasive species in Lake Erie.

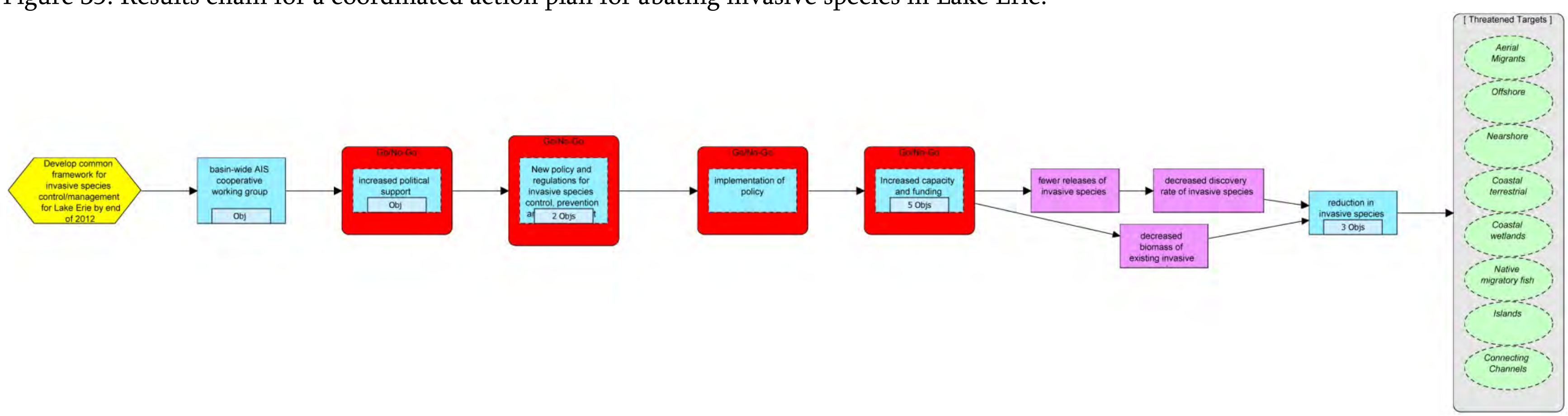

Figure 36: Results chain for developing a common framework for invasive species management in Lake Erie.

6.3.3. Terrestrial Strategy 2: Coordinate regulation of Common Reed in Canada and the U.S.

Strategic actions

- Incorporate required pesticide reforms in Ontario Invasive Plant Strategy.
- Enhance legislation and regulatory tools to prevent entry of new species

Results, objectives and measures

Objective 1: *By 2015* pesticide regulations in Ontario have been updated to allow for more efficient and rapid control of Common Reed.

- Measure 1: area of Common Reed.

Related strategies and initiatives

- Great Lakes Restoration Initiative Action Plan, Invasive Species Goal 5 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf
- Invasive Alien Species Strategy for Canada
- Ontario Invasive Plant Strategy
- Invasive Phragmites - Best Management Practices 2011 (Ontario): http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@biodiversity/documents/document/stdprod_089643.pdf
- Cooperative Weed Management Area in WLEB
- Conservation Authorities' (Ontario) watershed and/or shoreline management plans

6.3.4. Terrestrial Strategy 3: Improve coordination of early detection and rapid response of Common Reed.

Strategic actions

- Map current distribution of Common Reed.
- Improve prediction of potential areas for invasive based on water level forecasts, and share this information.
- Build the capacity of local groups and municipalities to manage Common Reed by having community-based workshops on management techniques.
- Build a clearing house of success stories and develop adaptive restoration BMPs.
- Clearly map distribution of major terrestrial invasive species to supported targeted approaches and coordination

- Increase detection using remote sensing and develop a baseline map of Common Reed distribution.
- Improved coordination with landowners
- Better examine and understand vectors

Results, objectives and measures

Objective 1: By 2015 new colonies of Common Reed are being managed within one year of detection.

Related strategies and initiatives

- Great Lakes Restoration Initiative Action Plan, Invasive Species Goal 4 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf

- Conservation Authorities' (Ontario) watershed and/or shoreline management plans

6.3.5. Terrestrial Strategy 4: Enhance coordination of outreach and marketing.

Recognized that these efforts are well underway. Objectives and measures not developed.

Related strategies and initiatives

- Great Lakes Restoration Initiative Action Plan, Invasive Species Goal 1 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf

- OFAH/MNR Invading Species Awareness program: http://www.invadingspecies.com/

6.3.6. Aquatic Strategy 1: Develop a coordinated framework for aquatic invasive species control/ management for Lake Erie by the end of 2013.

Strategic actions

- Build capacity of local municipalities and border services to detect aquatic invasive species.
- Work to modify existing regulations and policies to allow for rapid response (e.g. Clean Water Act).
- Coordinate approval of state/provincial/federal ballast water legislation.
- Develop specific BMPs and controls for aquatic invasive species, including integrated pest management and the restoration of native species and aquatic ecosystems.
- Coordinate data bases and mapping of species range and density/biomass
- Complete and coordinate risk assessments.
- Provide sustained investment and funding.

Results, objectives and measures

Objective 1: No new aquatic invasive species occur in Lake Erie by 2015.

- Measure 1: discovery rate/ number of exotic species

Objective 2: *By 2020, the range and/or biomass of existing invasive species has been reduced from 2012 levels by 10%.*

- Measure 1: biomass of invasive species
- Measure 2: range of invasive species

Related strategies in other initiatives

- Great Lakes Restoration Initiative Action Plan, Invasive Species Goal 4 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf
- Great Lakes Ballast Water Program http://www.dfo-mpo.gc.ca/science/publications/article/2011/06-13-11-eng.html
- Conservation Authorities' (Ontario) watershed and/or shoreline management plans

6.3.7. Aquatic Strategy 2: Build political support for policies and regulations that enable more effective control and management of aquatic invasive species.

Strategic actions

- Build a business case for a framework by engaging Great Lakes businesses and municipalities in supporting aquatic invasive species management.
- Complete a cost-benefit analysis for current aquatic invasive species and better quantify economic impacts.
- Provide economic incentive for compliance
- Improve screening policy regulations
- Coordinated outreach, education and marketing at key sites based on social science marketing

Results, objectives and measures

Objective 3: *A minimum of XM/ year is available for aquatic invasive species management from 2013-2020.*

Objective 4: *Federal, state and provincial policies and regulations support the control and management of aquatic invasive species by 2015.*

Related strategies and initiatives

- Great Lakes Restoration Initiative Action Plan, Invasive Species Goal s 4 and 5 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf
- Conservation Authorities' (Ontario) watershed and/or shoreline management plans

6.3.8. Aquatic Strategy 3: Improve coordination of prevention, early detection and rapid response of aquatic invasive species.

Strategic actions

- Conduct risk assessments
- Fund and form a basin-wide rapid response team
- Increased enforcement of existing baitfish laws

Results, objectives and measures

Objective 5: Develop an Early Detection and Rapid Response plan for Lake Erie aquatic invasive species by 2013.

Related strategies and initiatives

- Great Lakes Restoration Initiative Action Plan, Invasive Species Goals 1 and 4 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf.

- Department of Fisheries and Oceans Centre of Expertise for Aquatic Risk Assessment http://www.dfo-mpo.gc.ca/science/coe-cde/ceara/index-eng.htm.

- Conservation Authorities' (Ontario) watershed and/or shoreline management plans.

6.3.9. Aquatic Strategy 4: Demonstrate and quantify results of ecological restoration

Strategic actions

- Maintain refuges for native mussels in diked wetlands.
- Restore ecological separations.

Results, objectives and measures

Objective 6: By 2015, at least one project has been completed that shows the effectiveness of ecological restoration in controlling and managing aquatic invasive species.

Related strategies and initiatives

- Great Lakes Aquatic Nuisance Species Information System (GLANSIS): http://www.glerl.noaa.gov/res/Programs/glansis/nas_database.html .

- Asian Carp Control Strategy Framework: http://www.asiancarp.org/background.asp.

- Conservation Authorities' (Ontario) watershed and/or shoreline management plans.

6.4. Coastal conservation: Reducing the impact of housing and urban development and shoreline alteration

The nearshore waters, shoreline, and coastal uplands of Lake Erie are the region's most ecologically diverse and biologically productive systems. Due to the aesthetic appeal of coastal areas and the numerous economic benefits they offer, coastal systems are also among the most heavily used by people in the region and the most expensive to protect.

Urban development and shoreline alterations directly degrade and destroy habitat. While direct impacts such as these are most obvious, development and alterations also disrupt natural forces acting on the lakebed and shoreline, and alter flow and littoral circulatory patterns, nutrient cycles, sediment transport, and other coastal processes and pathways.

During the strategy workshop, ten strategies were identified to address the threat of shoreline development. Although all ten strategies are important to addressing the threat of incompatible shoreline development, we were only able to fully develop the top two priority strategies: 1) Build a business case for coastal conservation, and 2) Develop and implement a comprehensive education and outreach program for shoreline softening. It would be most effective if these two strategies occur concurrently as understanding and acceptance of the need for coastal conservation will be dependent on the availability of viable, cost effective shoreline protection alternatives that not only address the ecosystem priorities, but also meet the needs of shoreline property owners to protect their investments.

6.4.1. Priority strategies

A conceptual model depicting the causative linkages and contributing factors of housing and urban development and shoreline alterations as well as strategies for addressing these threats can be found in Figure 23. Six Lake Erie conservation targets, 1) Aerial Migrants, 2) Nearshore Zone, 3) Coastal Terrestrial, 4) Coastal Wetland, 5) Islands, and 6) Connecting Channels, are threatened by housing, urban development and shoreline alterations. Key stresses include altered sediment and nutrient transport, habitat destruction and degradation, loss of native plant and animal populations, decreased habitat connectivity, altered energy and nutrient flow, and altered hydrology. Reduced connectivity and habitat loss also is likely to reduce the likelihood that coastal species with low mobility can respond to warming temperatures by shifting northward into cooler habitats.

The primary drivers contributing to the increased negative impacts of housing, urban development and shoreline alterations can be divided into ten main categories: 1) lack of political will, 2) lack of integrated coastal plans, 3) lack of implementation of existing plans, 4) lack of participation in planning by landowners, 5) the high value/cost of coastal property, 6) lack of understanding of the coastal zone, 7) lack of scientific knowledge, 8) lack of enforcement of existing laws, 9) lack of funding, and 10) lake level uncertainty.

Once the conceptual model was finalized, the group brainstormed and vetted a list of potential strategies to address the issues identified in the conceptual model. A total of 10 different strategies were developed (Table 18).

Table 18: Priority strategies for housing and urban development and shoreline alterations in Lake Erie. Tier 1 strategies were considered of highest priority and were selected for more detailed strategy development. Tier 2 strategies are also important to address this threat.

Strategies	Priority
Build a business case for coastal conservation along Lake Erie	Tier 1
Develop and implement a comprehensive E/O for softening shoreline hardening	Tier 1
Identify pilot sites to implement research, inventory and monitoring priorities	Tier 2
Develop and implement multi-stakeholder integrated coastal plans	Tier 2
Mobilize a strong, compelling lobby for Great Lakes conservation	Tier 2
Identify funding and align language with existing funding opportunities	Tier 2
Revise shoreline regulations	Tier 2
Long-term, stable funding	Tier 2
Develop an integrated information management decision support system for the coast	Tier 2
Develop a stakeholder communication plan	Tier 2

Each breakout group at the workshop was charged with prioritizing their list of strategies and identifying the top choices to address in the next steps of the planning process. The group ranked each strategy both by potential conservation impact and feasibility. The two strategies that ranked the highest were: 1) Build a business case for coastal conservation, and 2) Develop and implement a comprehensive education and outreach program for shoreline softening.

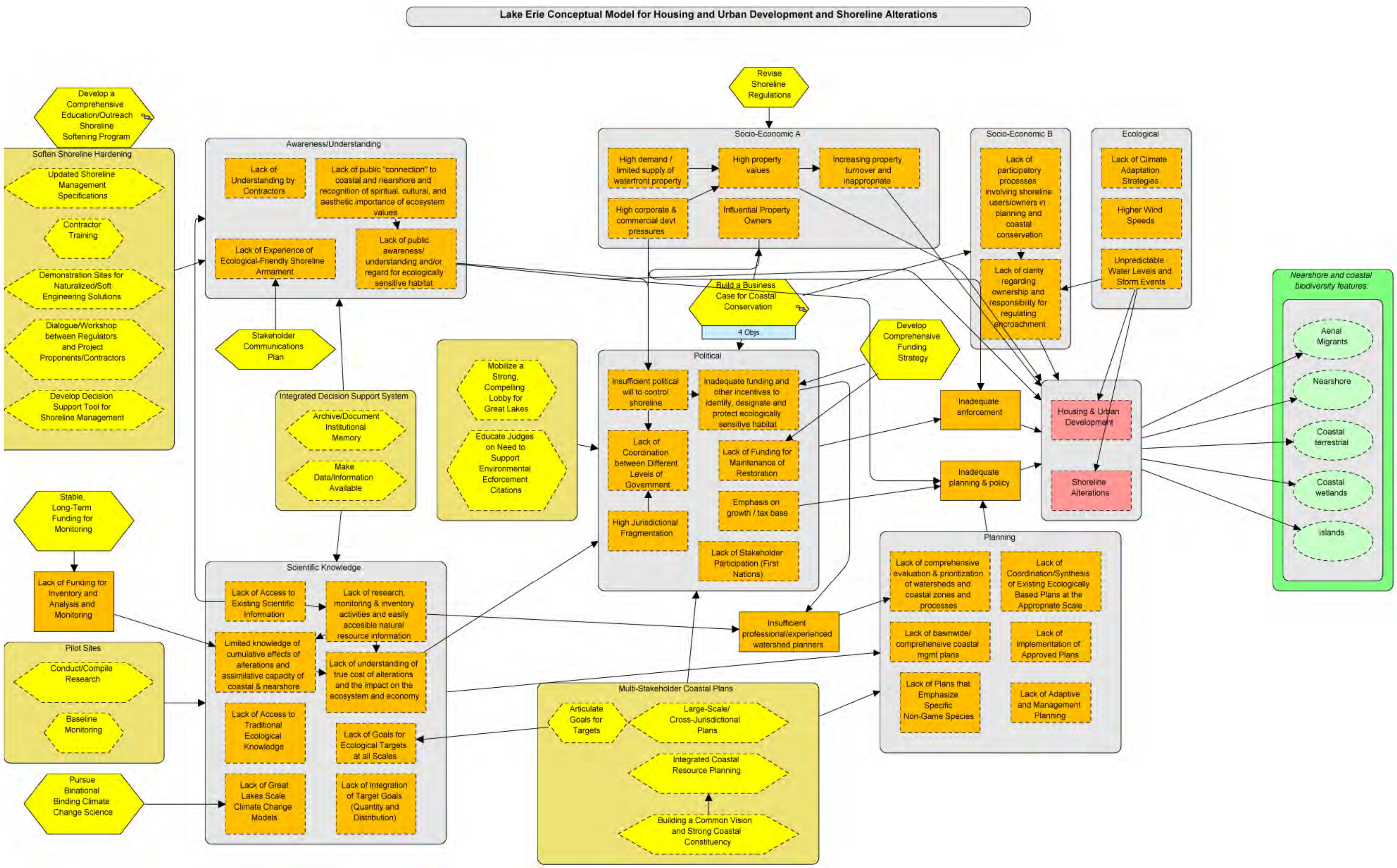

Figure 37: Conceptual model of housing and urban development and shoreline alterations in Lake Erie.

6.4.2. Strategy 1: Build a business case for coastal conservation

This strategy was chosen by the workshop participants primarily because it addresses the underlying problem of lack of funding that impacts many of the other strategies that were identified. The Great Lakes region in particular has suffered economically since 2001, and the economy of the Great Lakes region has continued to decline through the recent Great Recession into 2012. Despite significant federal investments in coastal restoration under the Great Lakes Restoration Initiative, funding for enduring coastal conservation efforts has suffered in the current economic climate. This has translated into critical government budget shortfalls, fewer local, regional, and state government employees able to address environmental issues associated with Lake Erie, and decreased attention to the environment. Ultimately, the goal of the business case for coastal conservation is to secure long-term stable funding at sufficient levels to reach and sustain a healthy Lake Erie ecosystem.

The business case will take a highly collaborative approach to determine detailed, defensible conservation goals within a pilot coastal area of Lake Erie in both Canada and the U.S. To the extent possible, each of these goals will be spatially explicit and be accompanied by detailed social, cultural, economic, and ecological benefits and associated costs. If the business case is successful in garnering support from key stakeholders, business sectors, agency decision makers, and politicians, we believe it will result in new dedicated funding for developing integrated coastal zone adaptive management plans, and implementing targeted conservation actions.

Strategic actions

- Complete a Request For Proposals (RFP) for the coastal business case/ economic study by January 2013
    - Develop an RFP for study (work with Sustain our Great Lakes and Karen Rodriguez (EPA))
- Create steering committee by June 2013
    - Determine specific communication strategy
- Identify a specific coastal area for pilot study based on set criteria by July 2013
- Complete baseline study for pilot areas(s) by 2014
    - Complete spatially-based analysis for pilot area(s)
    - Review/summarize similar economic studies (e.g., Lake Simcoe)
- Complete economic study for pilot area by July 2015.
- Develop standardized methods for assessing the health of the coastal zone

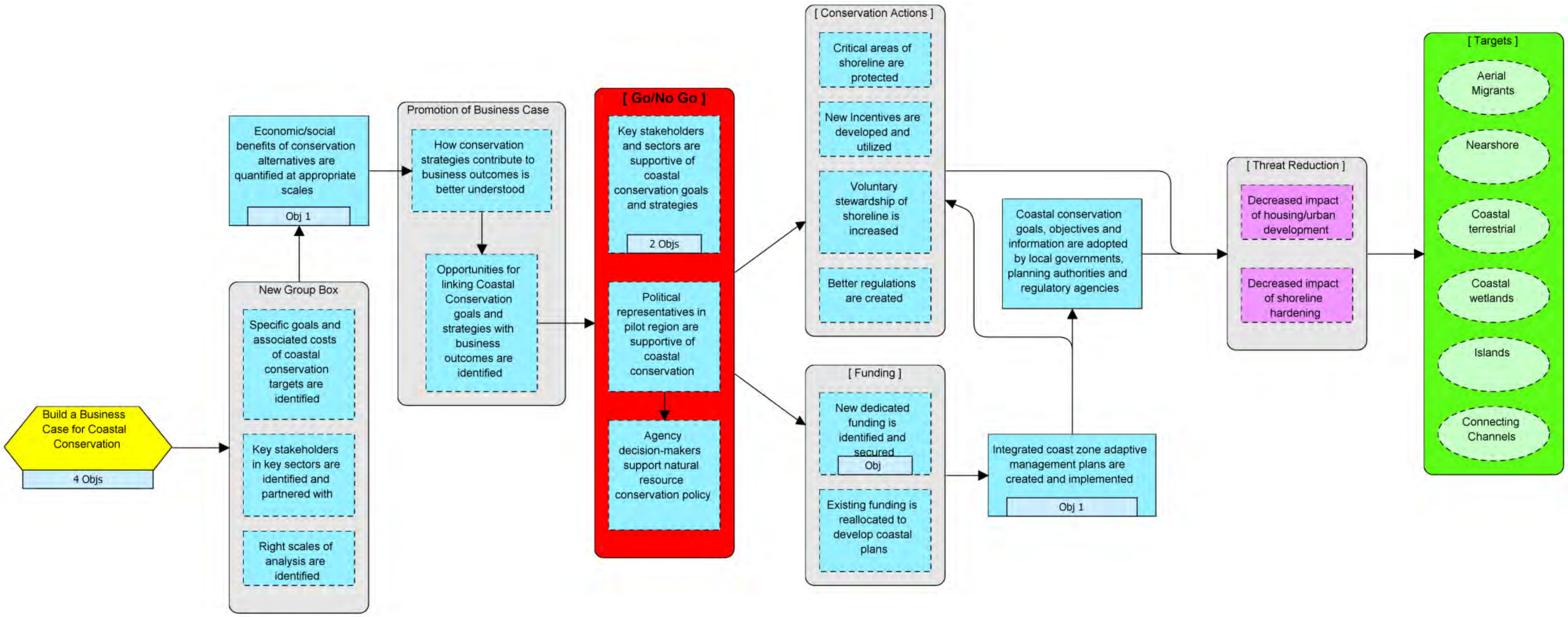

Figure 38: Results chain for building a business case for abating coastal threats in Lake Erie.

Results, objectives and measures

Result 1. Preliminary steps for developing the comprehensive business case are completed.

1 a. Specific goals and associated costs for coastal conservation are identified.

1 b. Key stakeholders in affected sectors are identified and partnered with.

1 c. Right scales of analyses are identified.

Result 2. Economic/social benefits of conservation alternatives are quantified at appropriate scales.

Objective 1: By 2015, the economic and social benefits of conservation alternatives at appropriate scales are quantified and documented for the pilot area.

Result 3. Materials for promoting Business Case are developed.

3 a. How conservation strategies contribute to business outcomes is better understood.

3 b. Opportunities for linking conservation goals and strategies with business outcomes are identified.

Result 4. Key support is secured.

4 a. Key stakeholders and sectors are supportive of coastal conservation goals and strategies.

Objective 2: Representatives of key affected stakeholders and sectors understand the business case for coastal conservation within one year of study completion.

- Measure 1: % of survey respondents in pilot area that state they understand the business case for coastal conservation

Objective 3: Key affected stakeholders and sectors issue statements or resolutions of support for business case within 15 months of completion of study.

- Measure 1: total # of resolutions from key stakeholders
- Measure 2: # of different sectors with supporting resolutions

4 b. Political representatives from the pilot region are supportive of coastal conservation goals and strategies

4 c. Agency decision-makers are supportive of natural resource conservation policy.

Result 5. Funding is identified and secured.

5 a. New dedicated funding is identified and secured.

Objective 4: By 2019, sufficient funding to support priority actions, including development of integrated coastal zone adaptive management plans for entire Lake Erie coastal zone, is secured.

- Measure 1: Total funding from existing sources within federal, state, and provincial agencies allocated to develop and implement new integrated coastal plans.
- Measure 2: New funding dedicated towards the development and implementation of new integrated coastal plans.

5b. Existing funding is reallocated to develop coastal plans.

Result 6. Conservation actions are implemented.

6a. Critical shoreline areas are protected.

6b. New incentives are developed and utilized.

6c. Voluntary stewardship of shoreline is increased.

6d. Better regulations are created.

Result 7. Integrated coastal zone management plans are created and implemented.

Objective 5: By 2022, integrated coastal zone adaptive management plans are created and being implemented across Lake Erie.

Result 8. Coastal conservation goals, objectives, and information are adopted by local government, planning agencies, and regulatory agencies.

Threat Reduction Result 1. Decreased impact of housing & urban development.

Objective 8: By 2030, Increase current level of ecological connectivity in the coastal zone (or along the shoreline) by an average of 15% (numbers will differ by coastal assessment unit)

Threat Reduction Result 2. Decreased impact of shoreline hardening.

Objective 9: By 2030, 20% or less of the Lake Erie shoreline will be in hardened condition (% will differ by coastal assessment unit)

- Measure 1: distance of hardened shoreline

Priority or opportunity areas for implementation

Western Lake Erie Basin (including both U.S. and Canadian portions of the basin) is currently a focal area of many agencies and organizations working in Lake Erie.

Related strategies and initiatives

- Great Lakes Restoration Initiative Action Plan, Nearshore goal 2, Habitat goal 3 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf

- Lake Michigan Biodiversity Conservation Strategy: Coastal Conservation– Develop and Implement coordinated planning efforts that effectively address the long-term viability of coastal conservation targets.

- Ohio Lake Erie Commission Balanced Growth Initiative.

- Grand Lake St. Marys Ohio: residents created a strategic plan regarding water quality that was promoted to new Governor and administration, who adopted recommendations and are implementing corrective actions.

- Great Lakes Compact in Ohio—initial standards were not accepted by many stakeholders, who were able to convince administration to revise standards in light of international agreement.

- Conservation Authorities' (Ontario) watershed and/or shoreline management plans

- The "NOAA Report on the Ocean and Great Lakes Economy of the United States" examines the economic contributions of the oceans and Great Lakes. The report presents data from the NOAA Coastal Services Center's Economics: National Ocean Watch (ENOW) dataset. A variety of visual representations of the data are included for the national, regional, and state levels - http://www.csc.noaa.gov/digitalcoast/publications/econreport

- Ontario's Proposed Great Lakes Protection Act and Draft Strategy: http://www.ene.gov.on.ca/environment/en/subject/great_lakes/index.htm

- Various Great Lakes St. Lawrence Cities Initiative publications and resolutions (http://www.glslcities.org/publications/reports.cfm)

Likely participating agencies and organizations

Federal, state/provincial, and watershed and shoreline management (e.g. Ontario Conservation Authorities) agencies, municipalities and Great Lakes St. Lawrence Cities Initiative

6.4.3. Strategy 2: Develop a comprehensive education/outreach shoreline softening program (healthy shorelines)

This strategy focuses on addressing both the retrofitting of existing shoreline alterations, and the prevention of future hardening of shorelines. Given the fact that up to 77% of the shoreline is hardened in parts of Lake Erie, this strategy will target those areas of the coastal zone that are of highest priority for maintaining and enhancing coastal biodiversity and processes. The ultimate goal of this strategy is to reduce average shoreline hardening to 20% or less across the lake. One of the biggest challenges to meeting this goal is the uncertainty of future lake levels in Lake Erie due to a variety of factors such as glacial rebound, riverbed scour (St. Clair River), and global climate change, which contributes to reduced ice cover and increased evaporation rates (see Appendix H). An additional obstacle is the lack of knowledge and appreciation of the coastal zone and its associated natural communities, plants, and animals.

The development of a comprehensive education/outreach shoreline softening program hinges on the development of a coastal management toolbox to facilitate best management practices along the shoreline. The toolbox will consist of several components: 1) a web-based coastal management decision support tool, 2) contractor training, 3) workshops for regulators and contractors, and 4) demonstration sites. An initial set of tools will be based on existing literature and a pilot project area, while a more robust version of the toolbox will be available once additional research has been conducted and coastal processes are better understood.

Strategic actions

- Conduct literature review on Great Lakes coastal processes, including impacts of shoreline alterations.
- Identify information/knowledge gaps on coastal processes to inform research priorities.
- Engage experts and scientists (agency, consultants, academic) actively studying coastal processes.
- Develop a unified definition of "soft shoreline" and related terms ("healthy shoreline").
- Assess current status of shoreline condition/impairment around the entire lake.
- Develop and implement monitoring protocols to evaluate changes in coastal condition. Identify pilot areas for shoreline softening demonstration projects
- Conduct study to evaluate effectiveness of different shoreline softening techniques.

Results, objectives and measures

The above strategic actions are intended to lead to a number of intermediate results and, ultimately, reduce the threats of housing & urban development and shoreline alterations. The results chain (Figure 39), lays out this sequence of results. Two groups of results early in the process—research and development and shoreline toolbox—are key to the success of the overall strategy, and will lead to improved planning and execution of development and shoreline modifications in coastal areas.

Result 1. Coastal processes are understood. The first three strategic actions all will help achieve this outcome.

Result 2. Research and development outcomes. There are four results related to research and development, one of which has a specific objective:

2a. Shoreline management specifications are updated;

2b. Priority areas are identified for retrofitting;

2c. Priority areas are targeted for prevention of shoreline alterations;

Objective 3: By 2018, a coastal condition assessment is completed, priority areas for conservation and restoration are identified, and goals and targets for softening and protection are established for priority areas.

2d. Cost/Benefits of various shoreline management strategies are understood.

Result 3. Pilot areas are identified.

Objective 1: By 2013, a pilot area for developing initial shoreline toolbox is identified.

Result 4. Baseline information and monitoring protocols are established.

Result 5. Shoreline toolbox developed. There are four results associated with the shoreline toolbox, and two specific objectives:

5a. Demonstration sites are created for naturalized/soft engineering solutions;

5b. Dialogue/workshop between regulators and project proponents/contractors are conducted;

5c. Contractor training is established;

5d. Decision support tool for shoreline management is developed.

Objective 2: *Within 12 - 18 months of developing monitoring protocols and documenting baseline information of pilot area, an initial coastal management decision support tool is developed and made available to the pilot region*.

Objective 3: *By 2018, a robust shoreline management toolbox is available for the entire Lake Erie coastal zone*.

Result 6. Increased trust between contractors and regulators.

Result 7. Ecological alternatives are proposed by contractors and requested by landowners.

Objective 4: By 2018, 100% of contractors that have been trained in ecological alternatives for shoreline management, include soft shoreline management practices in their recommendations to landowners.

Result 8. Better understanding of shoreline processes by stakeholders.

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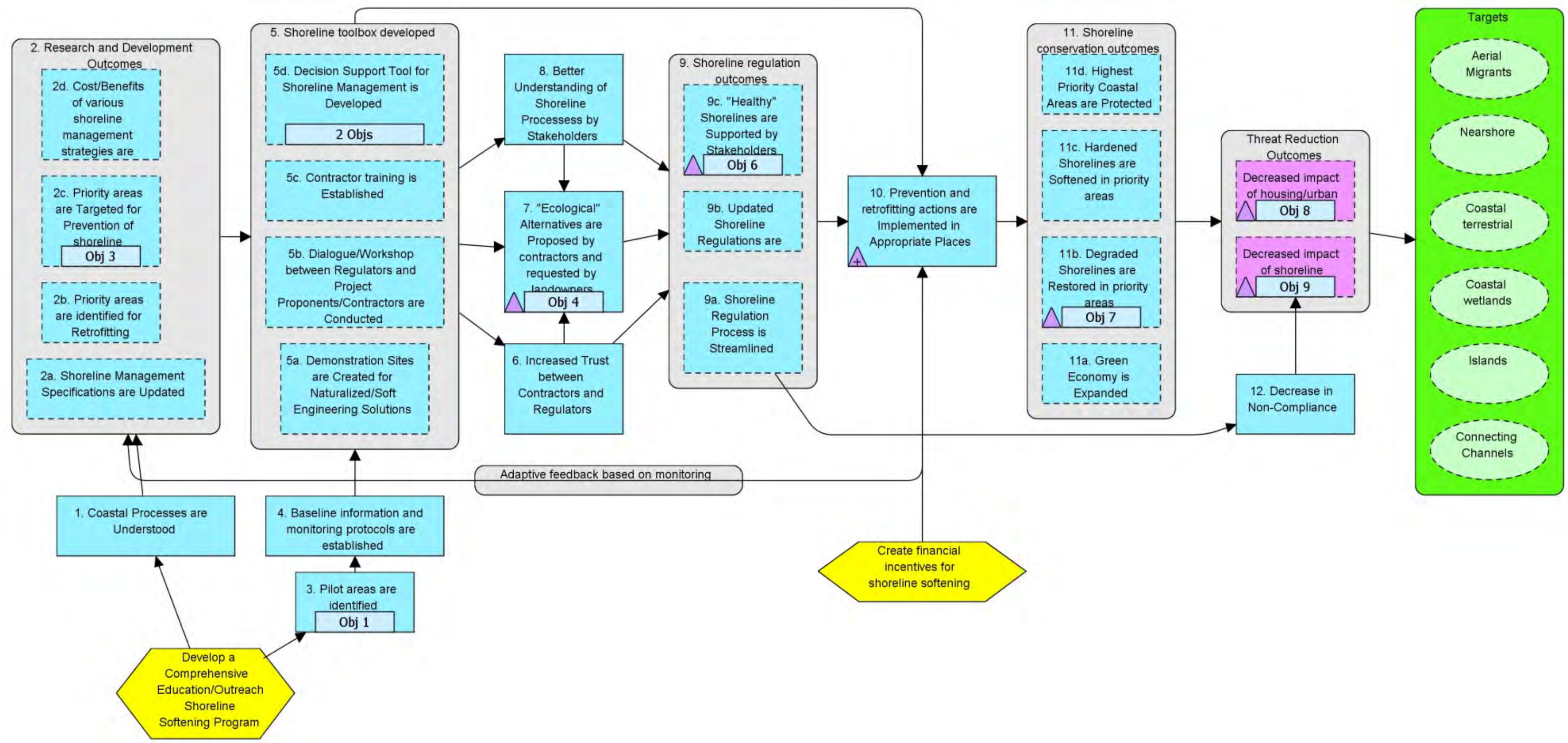

Figure 39: Results chain for developing a comprehensive education/outreach strategy for a shoreline softening program in Lake Erie

Result 9. Shoreline outcomes. This group of results includes three that related to regulations and social perceptions. They set the stage for compatible shoreline development actions.

9a. Shoreline regulation process is streamlined.

9b. Updated shoreline regulations are developed.

9c "Healthy" Shorelines are supported by Stakeholders. This result has one objective and associated measure.

Objective 5: By 2020, 75% of shoreline landowners and coastal stakeholders support "healthy shorelines."

- Measure 1: Percent of survey respondents that respond positively to improving the health of existing Lake Erie shorelines

Result 10. Prevention and retrofitting actions are implemented in appropriate places. This result can be assessed using the following two measures of shoreline permits.

- Measure 1: Percent of shoreline softening permits issued on an annual basis relative to all shoreline alteration permits issued (trend)
- Measure 2: Number of shoreline hardening permits issued on an annual basis (trend)

Result 11. Shoreline conservation outcomes. This set of outcomes comprises shoreline restoration and protection, as well as a related outcome of an expansion in the green economy.

11a. Green economy is expanded;

11b. Degraded shorelines are restored in priority areas;

Objective 6: By 2030, 95% of shoreline in priority biodiversity areas is in natural or "naturalized" condition

- Measure 1: meters of shoreline in priority areas in natural or naturalized condition

11c. Hardened shorelines are softened in priority areas;

11d. Highest priority coastal areas are protected.

Result 12. Decrease in non-compliance. This result follows the streamlining of shoreline regulation processes, and facilitates the threat reduction results.

Threat Reduction Result 1. Decreased impact of housing & urban development.

Objective 7: By 2030, Increase current level of ecological connectivity in the coastal zone (or along the shoreline) by an average of 15% *compared to 2010 levels (numbers will differ by coastal assessment unit - TBD).*

- Measure 1: Contagion – a fragstats GIS measurement

Threat Reduction Result 2. Decreased impact of shoreline hardening.

Objective 8: By 2030, 20% or less of the Lake Erie shoreline will be in hardened condition (numbers will differ by coastal assessment unit - TBD)

- Measure 1: distance of hardened shoreline

Priority or opportunity areas for implementation

Similar to other strategies, there is a lot of attention focused on the Western Lake Erie Basin. There was also a suggestion to focus this effort on coastal areas along the lake as opposed to the Connecting Channels.

Related strategies and initiatives

- LEBCS: Coastal Conservation– Develop and Implement coordinated planning efforts that effectively address the long-term viability of coastal conservation targets.
- Great Lakes Restoration Initiative Action Plan, Nearshore goal 2, Habitat goal 3 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf.
- Lake Michigan Biodiversity Coastal Strategy: Coastal Conservation– Develop and Implement coordinated planning efforts that effectively address the long-term viability of coastal conservation targets.
- Lake Erie LAMP .
- Ohio Coastal Management Program – Web-based coastal atlas that provides spatially based information on a variety of coastal activities and natural features.
- Michigan SeaGrant – has lead and helped implement several shoreline softening projects on or near the Detroit River.
- International Joint Commission has established the International Great Lakes-St. Lawrence River Adaptive Management Task Team to develop a detailed basin-wide adaptive management plan for addressing future water level extremes. Part of their work plan is to try to initiate (if the opportunities present themselves) some risk assessment pilot studies, so there could be some synergies. http://ijc.org/stlawrencerivertaskteam/ .
- Ontario's Proposed Great Lakes Protection Act and Draft Strategy: http://www.ene.gov.on.ca/environment/en/subject/great_lakes/index.htm.
- Conservation Authorities' (Ontario) watershed and/or shoreline management plans and permit approval processes for shoreline protection measures and implementation of shoreline softening projects.

Likely participating agencies and organizations

- Michigan, Ohio, Pennsylvania, and New York Sea Grant.
- US Environmental Protection Agency.
- US Army Corp of Engineers.
- Conservation Authorities (Ontario).
- Ontario Ministries of Natural Resources and Environment, Environment Canada, Department of Fisheries and Oceans.
- Michigan Department of Environmental Quality.
- Michigan, Ohio, Pennsylvania, and New York Coastal Management Programs.

6.5. Reducing the impact of urban non-point and point source pollutants

While the Great Lakes region's U.S. population increased by 3.8 percent from 2000 to 2010 (less than a third of the national growth rate) the 2010 Census found that the trend shifting the population from rural to urban areas continues.[20, 21] In Ontario Canada, the 2011 Canadian Census reports that the population increased by 5.7 percent while density of households increased 14.1% over the last 5 years.[22] Of the 15 U.S. counties bordering Lake Erie and its connecting channels, 11 are more than 50% urbanized, and in all 15 counties more than 50% of the population resides in urbanized areas or urban clusters (Figure 40).[23, 24] There are a number of major cities along Lake Erie and its connecting channels, including: Buffalo, New York; Erie, Pennsylvania; Toledo, Ohio; Port Stanley, Ontario; Monroe, Michigan; Sandusky, Ohio; Cleveland, Ohio; Windsor, Ontario; Detroit; Michigan. In urban and suburban areas, much of the land surface is covered by buildings and pavement, which do not allow rain and snowmelt to soak into the ground. Instead, most developed areas rely on storm drains to carry large amounts of runoff from roofs and paved areas to nearby waterways. Stormwater runoff carries pollutants such as oil, dirt, chemicals, and lawn fertilizers directly to streams and rivers, where they seriously harm water quality. The most recent U.S. National Water Quality Inventory reports that runoff from urbanized areas is the third-largest source of impairments to surveyed lakes. That finding is reflected in the threat

[20] US Census, http://files.cfra.org/pdf/census-brief1-population.pdf

[21] The urban population of the United States increased from 79% in 2000 to 80.7% in 2010. US Census.

[22] Statistics Canada, 2011 Census. http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/index-eng.cfm

[23] US Census, Percent Population Residing in Urban Areas by County: 2010 (This choropleth map shows the percent of the total population in each county or county equivalent that reside in either urbanized areas or urban clusters.) http://www.census.gov/geo/www/maps/2010_census_UA_maps/imgs/UA2010_Urban_Pop_Map.pdf

[24] The Census Bureau identifies two types of urban areas: "urbanized areas" of 50,000 or more people and "urban clusters" of at least 2,500 and less than 50,000 people.

assessment completed for the LEBCS (see section 5.2.4), and working with experts from around the Lake Erie basin, we developed a broad strategy to improve stormwater management.[25]

6.5.1. Priority strategies

To deal with the threats related to urban non-point source pollutants, the breakout group at the strategy workshop held in Detroit constructed a conceptual diagram depicting the targets, threats, contributing factors, and a number of potential strategies (Figure 26). Although the strategies overlap and could potentially be articulated in a number of ways, there were some groupings that emerged, including Green Infrastructure, Atmospheric Load Reduction, Emerging Contaminant Reduction, Regulatory Approaches, and Watershed Management Plans, as well as a few independent strategies such as AOC remediation, PCB cleanup, Incentives for Cleanup and Remediation, and Clean Marina Program. Among these, after evaluating the overall impact and feasibility, the group identified three as top priorities: Watershed Management Plans, AOC Remediation, and Green Infrastructure (Table 19).

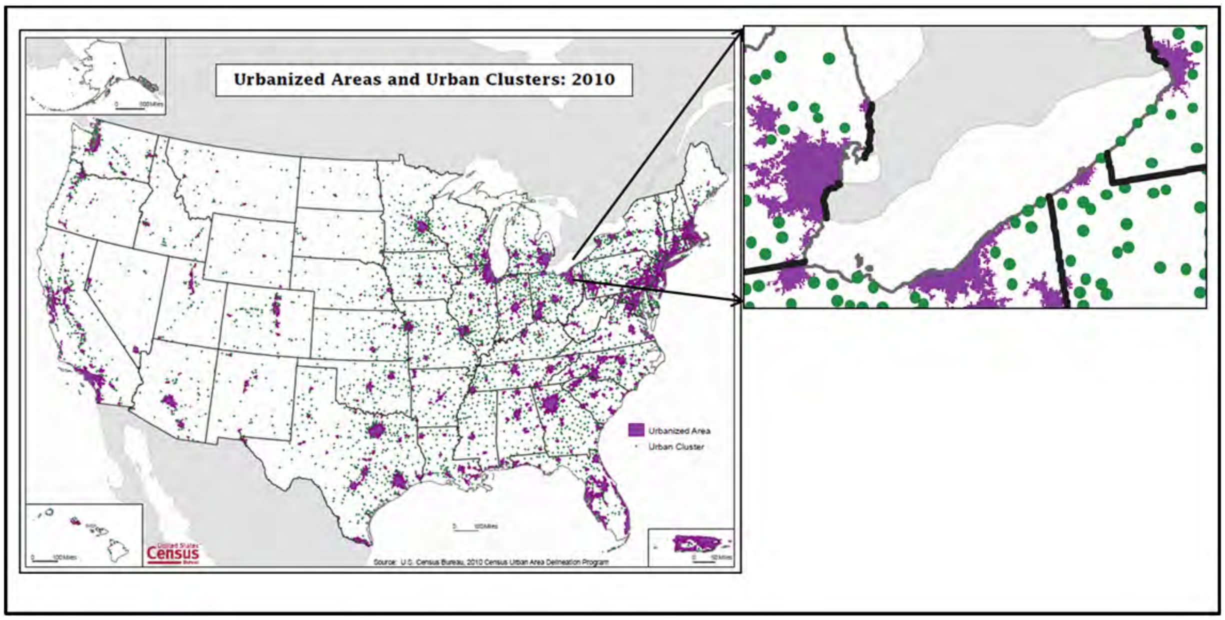

Figure 40. Urbanized areas and urban clusters in the U.S., with closeup showing Lake Erie coastal areas[26].

[25] EPA, Protecting Water Quality from Urban Runoff: Clean Water is Everybody's Business. EPA 841-F-03-003.

[26] US Census, Urbanized Areas and Urban Clusters: 2010. http://www.census.gov/geo/www/maps/2010_census_UA_maps/imgs/UA2010_UAs_and_UCs_Map.pdf

Table 19: Priority strategies to address urban non-point source pollutants in Lake Erie. Tier 1 strategies were considered of highest priority and were selected for more detailed strategy development. Tier 2 strategies are also important to address this threat.

Strategies	Priority
Watershed Management Plans	Tier 1 - improve stormwater management
Green Infrastructure	Tier 1 - improve stormwater management
AOC remediation	Tier 2
“Regulatory”	Tier 2
Clean Marinas Program	Tier 2
Alt. load dredging	Tier 2
Brownfield clean-up	Tier 2
Emerging Contamination Reduction	Tier 2
PCB reduction	Tier 2

Experts agreed that AOC remediation is proceeding well, and that further development of the Watershed Management Plans and Green Infrastructure strategies would represent a more substantial contribution to abatement of urban non-point source pollutants. The single strategy described below Improve Storm Water Management—incorporates aspects of watershed management plans and green infrastructure.

6.5.2. Strategy 1: Improve storm water management

This broad strategy incorporates both mitigation of storm water issues on existing developed lands through better enforcement of regulations and retrofitting of existing developments, and prevention of storm water problems on newly developed lands through a variety of mechanisms. The strategy is based on an assumption that individual municipalities can benefit from pooling resources to help meet storm water permit requirements by collaborating with other watershed partners and stakeholders (Figure 27). Improving stormwater management is recognized as a pervasive, multi-faceted (i.e., science, policy, and coordination) challenge, and one that is likely to increase in importance, as peak storm intensities tend to increase with increasing air temperatures (Appendix H).

Recognizing that regulations and governance structures differ among states and between the U.S. states and Ontario, the strategy is general but contains specific details where appropriate. Terminology also carries distinct implications in various jurisdictions; for example, in the US, storm water management is a broad approach that increasingly incorporates Low Impact Development (LID) and Green Infrastructure (GI). Similarly in Ontario, the term storm water management specifically refers to conventional systems with the emergence of LID/green infrastructure (http://www.ene.gov.on.ca/environment/en/subject/stormwater_management/index.htm) and

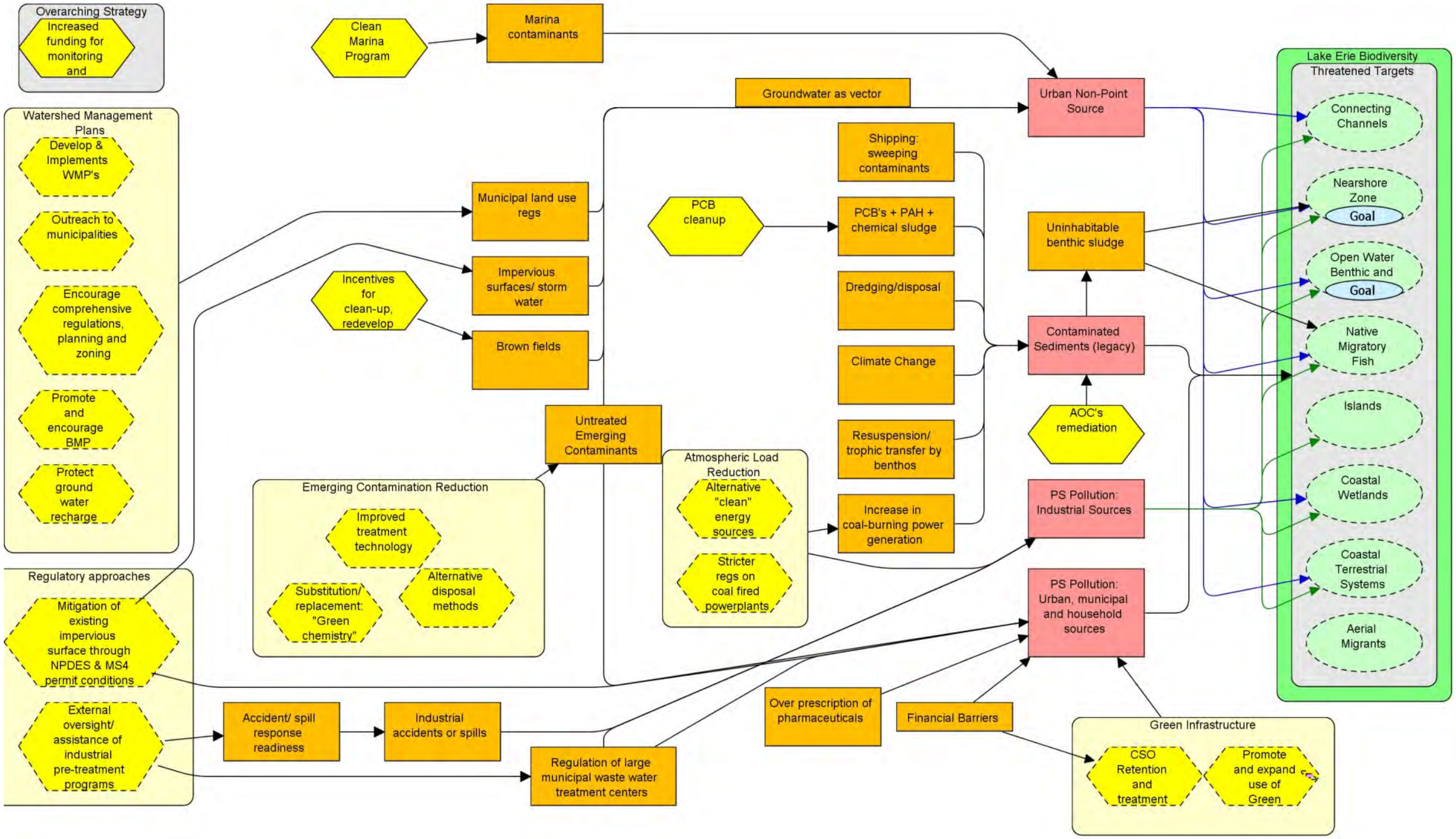

Figure 41: Conceptual model of urban point and non-point sources of pollution in Lake Erie.

constructed retention ponds. Clearly, implementation of this strategy will require adaptation to state/provincial, regional, and local regulations and governance.

Strategic actions

- Improve aspects of regulations; in Ontario, the Environmental Compliance Approval process applies to stormwater works, many of which are located in urban settings, and is administered by the Ontario Ministry of Environment. In the US, MS4 permits provide the vehicle for a regulatory approach. Both need to be made more specific and comprehensive.

- Implement LID and BMPs as appropriate including in sensitive areas: Identify sensitive areas including recharge areas, however, some additional care may be required in some cases for infiltration-LIDs to mitigate potential for water quality impacts on groundwater.

- Identify and develop sustainable funding mechanisms. For example, at the state level, a new environmental bond could be developed by legislature. Another potential mechanism in the U.S. could be to expand the existing State Revolving Fund to support GI and other related activities.

- In U.S. states bordering Lake Erie and Ontario, develop storm water utilities and/or storm water fees. Individual municipalities would pursue this option where feasible, and where sufficient support exists. This would require clarifying legislation that distinguishes taxes from fees, and how those rules apply to storm water utilities. For example, an effort by the city of Lansing, Michigan, to develop storm water utilities was questioned and is being reviewed by the Michigan Supreme Court. Other municipalities have storm water utilities that aren't being challenged. There seems to be a lack of political will to push for more storm water utilities; public awareness and private sector support are key for developing storm water utilities.

- Complete analyses of impervious surfaces.

- Outreach and awareness. These actions can occur through a variety of mechanisms at Federal, State, regional, and local levels. There is a need for better collaboration, to reduce duplication and improve efficiency. Key sources of information for use in outreach efforts include a recent Brookings Institute study (REF) on benefits of Great Lakes restoration. An ongoing study by Great Lakes United, and a Green Infrastructure Ontario Coalition/Ecojustice report that presents a strong case for improved policies and investments to support green infrastructure (REF). Outreach on reducing non-point pollution has been occurring for several years under MS4 permit regulations. MS4 outreach has been focused on BMPs at the household level, not stormwater management; one approach could be to expand the focus of this existing program. Experts identified a real need for refining collaborations with partners engaged in outreach, such as the Southeast Michigan Partners for Clean Water.

Results, objectives and measures

The above actions are intended to lead to a number of intermediate results that would help to reduce the threats of urban point and non-point sources of pollution.

Result 1. Long term costs of stormwater management are reduced or other co-benefits are realized. This result reflects savings and avoided costs that are realized as LID and GI practices are increasingly implemented (e.g. co-benefits include energy savings by reducing urban heat island effect).

Result 2. Public is aware of and supports stormwater/NPS management and increased funding. Outreach and education efforts, focused on the general public as well as industry, lead to this result.

Result 3. Sustainable Funding Mechanism(s) in place. There are several potential mechanisms that could be employed, though momentum and support can be difficult to achieve. Funding is a major challenge for implementation of watershed management approaches (at least in MI), so this is an important intermediate result.

Result 4. Prevention: Municipal regulations, planning and zoning, for new development and redevelopment address storm water. These regulations should incorporate retrofitting. An increasing number of communities are enacting progressive regulations already.

Objective 1: By 2020, (some percentage) of municipal stormwater (regulations/ordinances/bylaws) require or incorporate LID, GI, or other BMPs.

Result 5. New developments and redevelopments incorporate BMP's and protect sensitive features. Sensitive features should include natural wetlands and riparian areas, as well as areas of high groundwater recharge (potential or actual).

Result 6. Mitigation: Enforce regulations and retrofit existing developments where appropriate. Enforcement has typically been limited by lack of sustainable funding, but also political barriers. This result can be achieved by actions to establish sustainable funding and increasing public support.

Result 7. Reduction of storm water runoff impacts. Reduced runoff volume will be a major outcome of this strategy, and will lead to reduced pollution and associated impacts.

Threat abatement result: Reduction of urban non-point source pollution.

- Measure 1. Impervious surfaces. Municipalities or regional governments increasingly monitor the extent of impervious surfaces.
- Measure 2. Improvement in biological communities in tributary watersheds. These communities are often monitored as part of an approved watershed management plan.
- Measure 3. Loads in TMDL watersheds. These loads can include total suspended solids, chloride, nutrients, and others.
- Measure 4. Stormwater volume and local water balance. This measure can be tracked through monitoring or through modeling. USGS stream gauges can provide data to develop flow curves; In MI, the Non-Point Source program is considering setting stormwater volume reduction goals, and in Southeast Michigan the Green Infrastructure Vision being developed by SEMCOG incorporates this measure.
- Measure 5. Beach closures (days/ year).

Threat abatement result: Reduced CSO events. New developments that incorporate GI, LID, and BMPs can lessen the burden on existing combined sewer systems, resulting in fewer CSOs.

- Measure 1. Stormwater volume. USGS stream gauges can provide data to develop flow curves; In MI, the Non-Point Source program is considering setting stormwater volume reduction goals, and in Southeast MIr the Green Infrastructure Vision being developed by SEMCOG incorporates this measure. Flow rate/volume could also be measured in the catch basin/sewer. Monitoring flow at the CSO outfalls provide some data, but cannot identify those that are contributing the most to the flow and what actions at the source are reducing the flow.

GOALS FOR AFFECTED TARGETS:

There are two targets particularly affected by urban non-point and point source pollutants—Nearshore Zone and the Open Water Benthic and Pelagic System. Goals that could be advanced through this strategy include:

Improved benthic community in the Open Water Benthic and Pelagic System, due to increased dissolved oxygen levels, and reduced Harmful Algal Blooms in the Nearshore Zone.

- Measure 1: water quality (could use Dissolved Oxygen in Connecting Channels or Nearshore Zone).
- Measure 2: pollutant loads; could use sediments (TSS), nutrients (nitrogen or phosphorus), or contaminants (chloride) in the Nearshore Zone or Connecting Channels, or as measured in tributaries near the lake.
- Measure 3: Improved benthic community due to increased dissolved oxygen levels,
- Measure 4: Reduction in harmful algal blooms.

Priority or opportunity areas for implementation

The above strategies and actions for reducing urban non-point pollution are not spatially explicit. In fact, there are many regional, county, and municipal governments that are tackling this issue and provide opportunities for furthering green infrastructure strategies. This list is not meant to be comprehensive, but provides some examples from around the lake:

- Southeast Michigan. The Southeast Michigan Council of Governments (SEMCOG) was recently awarded a Sustainable Communities Regional Planning Grant from U.S. Housing and Urban Development, effective February 15, 2011-February 14, 2014. A key component of this grant is developing a Regional Green Infrastructure Vision.

- Detroit, MI. The city of Detroit recently completed a Water Agenda (Detroit City Council Green Task Force, 2012).

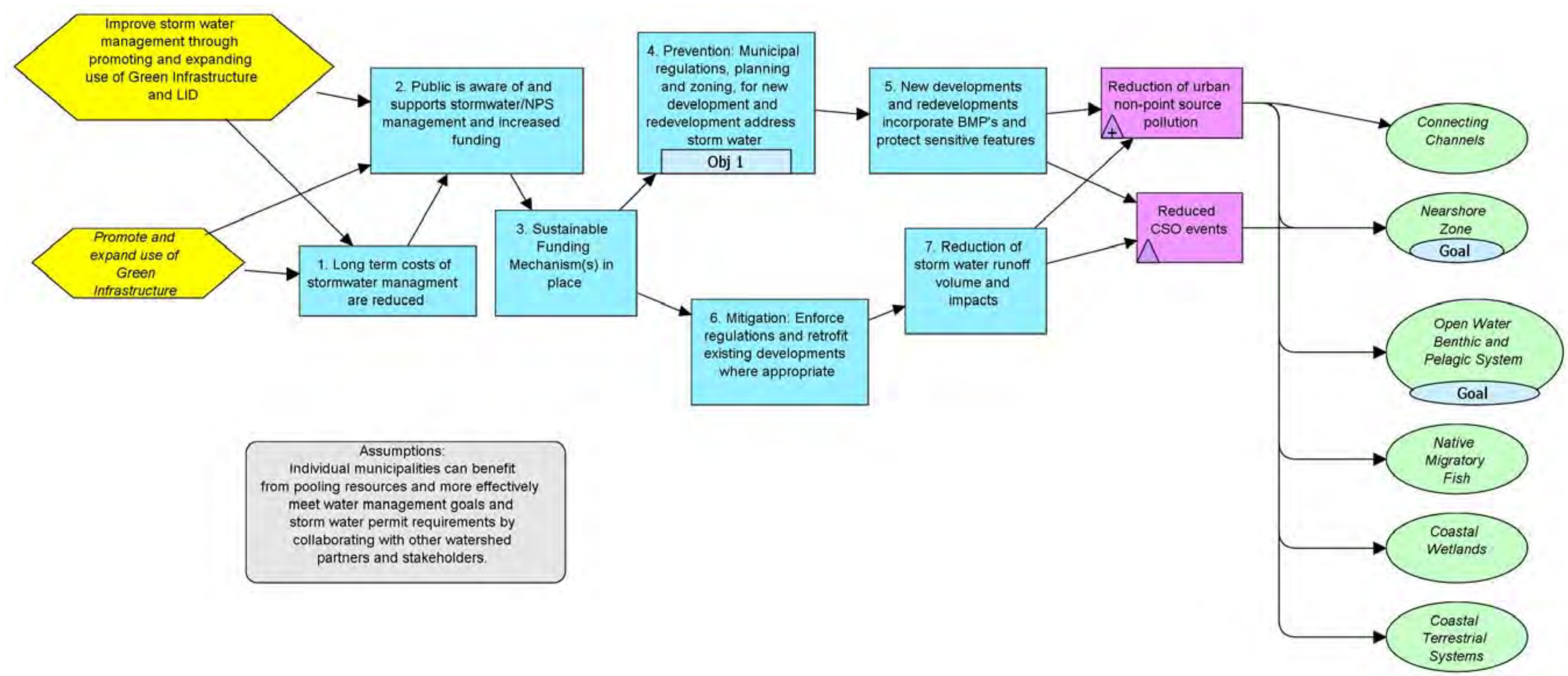

Figure 42: Results chain for the strategy to improve storm water management through promoting and expanding the use of green infrastructure and low impact development.

- Buffalo, NY. The City of Buffalo, Buffalo Niagara Riverkeeper and Buffalo Sewer Authority are collaborating on major green infrastructure demonstration project in Buffalo's Delaware District to reduce raw sewage overflows (http://bnriverkeeper.org/2012/08/buffalo-niagara-riverkeeper-joins-the-city-of-buffalo-to-celebrate-major-water-quality-improvement-project/).

- Erie, PA. Erie County, PA has produced guidance for stormwater managers in 38 municipalities and has completed a Phase II report and Model Stormwater Ordinance (http://www.eriecountyplanning.org/index.php?page=stormwater)

Related strategies and initiatives

- The report "Delisting Targets for Fish/Wildlife Habitat and Population Beneficial Use Impairments for the Detroit River Area of Concern" (Schrameck et al. 2009) lists several initiatives and activities related to cleanup of contaminants and reductions in pollution sources in the Detroit River AOC.

- Canada-United States Strategy for the virtual elimination of persistent toxic substances in the Great Lakes basin: http://www.epa.gov/glnpo/bns/index.html.

- Great Lakes Restoration Initiative Pollution Prevention grants.

- Great Lakes United study: "Improving Water Management in the Great Lakes Basin" funded through the Great Lakes Protection Fund. This six-month study seeks "…to identify the ecological benefits and explore the financial rationale for pursuing water conservation and green infrastructure practices, and test how this information—when combined with effective knowledge transfer techniques—can drive better water management throughout the Great Lakes region. "Ontario's Proposed Great Lakes Protection Act and Draft Strategy: http://www.ene.gov.on.ca/environment/en/subject/great_lakes/index.htm.

- Ontario's Water Opportunities Act strengthens water efficiency and sustainable water planning for municipalities: http://www.ene.gov.on.ca/environment/en/legislation/water_opportunities/index.htm.

- A current resource of information is "Health, Prosperity and Sustainability: The Case for Green Infrastructure in Ontario" (http://greeninfrastructureontario.org/report) which is co-authored by the Green Infrastructure Ontario Coalition and Ecojustice. The report draws on input from diverse stakeholders and existing research to present a strong case for improved policies and investments to support green infrastructure in the province.

- Conservation Ontario's 2010 report "Integrated Watershed Management: Navigating Ontario's Future." http://www.conservation-ontario.on.ca/watershed_management/reports/IWM_WaterMgmtFramework_Final_Jun2.pdf There are also a variety of plans created by Conservation Authorities, which can be found through Conservation Ontario's website: http://www.conservationontario.ca/find/index.html

- Various Great Lakes & St. Lawrence Cities Initiative publications and resolutions (http://www.glslcities.org/publications/reports.cfm), including their Declaration on Water Sustainability: http://www.glslcities.org/greencities/SMWM/Declaration_v3.pdf

- Great Lakes Restoration Initiative Action Plan, Toxics goal 2 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf

- The Southeast Michigan Council of Governments is developing a green infrastructure vision for the 7 county region bordering Lake Erie and its connecting channels. This project began in October 2011 and is on schedule to be completed in March 2014. SEMCOG is engaging stakeholders through Task Force and topic-specific resource teams and visioning workshops; defining green infrastructure for Southeast Michigan; benchmarking the state of green infrastructure in the region in terms of benefits, including impacts on water, air, land, and the economy; determining the future of green infrastructure in the region; and will provide recommendations on how to achieve the vision. [27]

- Great Lakes & St. Lawrence Cities Initiative, Declaration on Water Sustainability: http://www.glslcities.org/greencities/SMWM/Declaration_v3.pdf

Likely participating agencies and organizations

- Federal, state/provincial, and watershed and shoreline management (e.g. Ontario Conservation Authorities) agencies, municipalities and Great Lakes St. Lawrence Cities Initiative.

6.6. Improving connectivity for streams fragmented by dams and barriers

Dams and barriers in Lake Erie are considered significant threats to Migratory Fish as well as Nearshore and Coastal Wetland Systems. Dams and barriers are anthropogenic structures that block or disrupt connectivity among water bodies and therefore disrupt movement patterns for aquatic (and sometimes terrestrial) organisms or disrupt functional processes, such as movement of materials (e.g., woody debris, sediment, nutrients). For the purposes of this strategy, dams and barriers include structures like dams and poorly installed road-stream crossings that disrupt movement within Lake Erie tributaries, but also dikes which isolate coastal wetlands from other nearshore habitats.

6.6.1. Priority strategies

A conceptual model depicting the causative linkages, contributing factors, and opportunities for dams and barriers can be found in Figure x. Four Lake Erie conservation targets - Migratory Fish, Nearshore Zone, Coastal Terrestrial Systems, and Coastal Wetland - are threatened by dams and barriers through a

[27] SEMCOG Green Infrastructure Task Force: http://www.semcog.org/Sustainability_GreenInfrastructureTaskForce.aspx

variety of stresses, including blocked migrations of fish and other aquatic organisms, altered hydrologic regimes, altered sediment regimes, and altered nutrient regimes. The primary barriers that cause these stresses in Lake Erie are dams, poorly installed road-stream crossings, and dikes. The factors that influence the presence and future of these barriers can be divided into two groups. Factors that create pressure to keep barriers include financial costs of removal, aesthetic values, and risk of further invasive species spread. Factors that create pressure to remove or improve a given barrier include risk of failing infrastructure and associated costs, management objectives to improve fisheries and/or ecological conditions, and aesthetics. Some additional incentive to improve infrastructure may occur as increasing air temperatures (climate change) promote stronger storms, leading to higher potential for failure of outdated or undersized road-stream crossings and dams.

Strategies specifically to address dams and road stream crossings included prioritization and decision tools to maximize benefits of barrier removal, relative to risks. Strategies to address diking include working with agencies and land managers to promote more balanced management with multiple benefits. Other strategies were identified that would apply to all barrier types including outreach to increase barrier funding and guidance to local entities, watershed management plans that better consider the needs of Lake Erie, and the involvement of economic stakeholders in linking environmental health and ecosystem services with the regional economy. These strategies were combined into five choices (Table 20) from which the group elected to work on developing a decision tool for ranking dam and barrier removal. Each strategy proposed would contribute to advancing connectivity restoration.

Table 20: Priority strategies for dams and other barriers in Lake Erie. Strategies were given a priority rank and only the two best ranked strategies were fully developed.

Strategies	Priority Rank
Dams and connectivity	1
Road-stream crossing connectivity	1
Promote multiple objective management of diked wetlands	2
Set thresholds based on flow needs	3
Prevent future barriers	4

6.6.2. Strategy 1: Increase connectivity to Lake Erie focusing on first barriers

The strategy developed in the workshop is to increase connectivity to Lake Erie focusing on first barriers. This strategy is intended to abate stresses from dams and barriers (primarily culverts), which include altered hydrology, nutrient exchange, sediment regime, thermal regime and habitat access, to benefit Coastal Wetlands, the Nearshore Zone, and Native Migratory Fish.

Strategic actions

- Select prioritization criteria with input of full range of stakeholders and managers.

- High ecological benefit, low cost barrier projects are identified for immediate action.
- Rate barriers/rivers based on metrics of ecological significance, economics, risks, and opportunity.
- Update watershed plans with recommendations to repair, replace or prevent barriers.

Results, objectives and measures

The strategic actions listed above would lead to the following immediate, near and longer term results ultimately accomplishing the removal of first barriers (see Figure 28).

Result 1. International management groups use decision tool to prioritize critical watersheds/barriers.

> *Objective 1: By 2015 international management groups (US, Ontario, tribes/first nations) would use the decision tool to set priorities for connectivity restoration across Lake Erie or large sub-regions of the lake. This would include asking groups like the National Fish Habitat Action Partnership (NFHAP) to promote use of the tool.*

Result 2. Municipalities use decision tool for cost-benefit analysis of barrier removal/improvement projects.

This tool would be able to be used for assessments of individual dams so that local dam owners, such as municipalities, can weigh the benefits and costs of dam removal on the local and regional economy, including local and regional natural resources.

Result 3. Watershed plans incorporate repair/remove replace recommendations, if applicable.

If the results of regional analyses from the tool are effectively communicated to local watershed planners, updates of watershed plans should reflect the dam priorities identified by the tool. This would result in greater ties between watershed planning efforts and the resources of Lake Erie and should result in greater removal rates for priority barriers.

> Objective 2: *By 2025 all applicable watershed plans have incorporated the recommendations for addressing barriers generated through the prioritization process.*

Result 4. Resources directed to priority barriers.

Priority barriers would include those identified through a quick cost-benefit review and those identified through a much more detailed collection and evaluation of data about the ecological significance of the stream, the economic factors related to the dam or other barrier, the risks of spread of invasive species and/or pathogens, and the current opportunity due to social and political factors. One key means to director resources is for granting agencies to incorporate the priorities into their criteria.

Objective 3: *By 2016 requests for proposals will reference priority barriers (Great Lakes Restoration Initiative, U.S. Fish and Wildlife Service fish passage program, Canada-Ontario Agreement, Great Lakes Fish and Wildlife Restoration Act, GLFER, NFWF)*

Result 5. Priority barriers are removed or improved.

Obviously this result involved many intermediate results to accomplish including permitting, funding, public support, etc. Each removal project would need to have its own results chain essentially.

Result 6. Multiple watersheds have connectivity restored.

Objective 4: *By 2020, 25% of all habitat types are connected to Lake Erie.*

Objective 5: By 2020, there is at least one viable run of walleye in each applicable region of Lake Erie.

The assumption here is that if we are able to use the tool to prioritize a suite of barrier removal and improvement projects, that overall a significant increase in lake to river connectivity could be accomplished by better targeting existing programs that address fish passage and garnering additional resources. Being able to say more exactly what it would take to accomplish this 25% connectivity would be an important objective for the development of the decision tool.

Priority or opportunity areas for implementation

Strategy involves identification of priorities for first barrier removal.

Related strategies and initiatives

- Lake Erie LaMP Objectives 1 and 6. http://www.epa.gov/greatlakes/lamp/le_2008/ .
- Great Lakes Fisheries Commission Lake Erie Environmental Objectives. http://glfc.org/lakecom/lec/LEC_docs/other_docs/EOs_July5.pdf .
- The Council of Lake Committees is developing a protocol for sharing information among potentially affected agencies that can lead to a transparent decision making process that considers removal of dams and barriers that could affect Great Lakes fish communities.
- Great Lakes Restoration Initiative Action Plan, Habitat goal 2 http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf .
- Conservation Authorities' (Ontario) watershed and/or shoreline management plans.

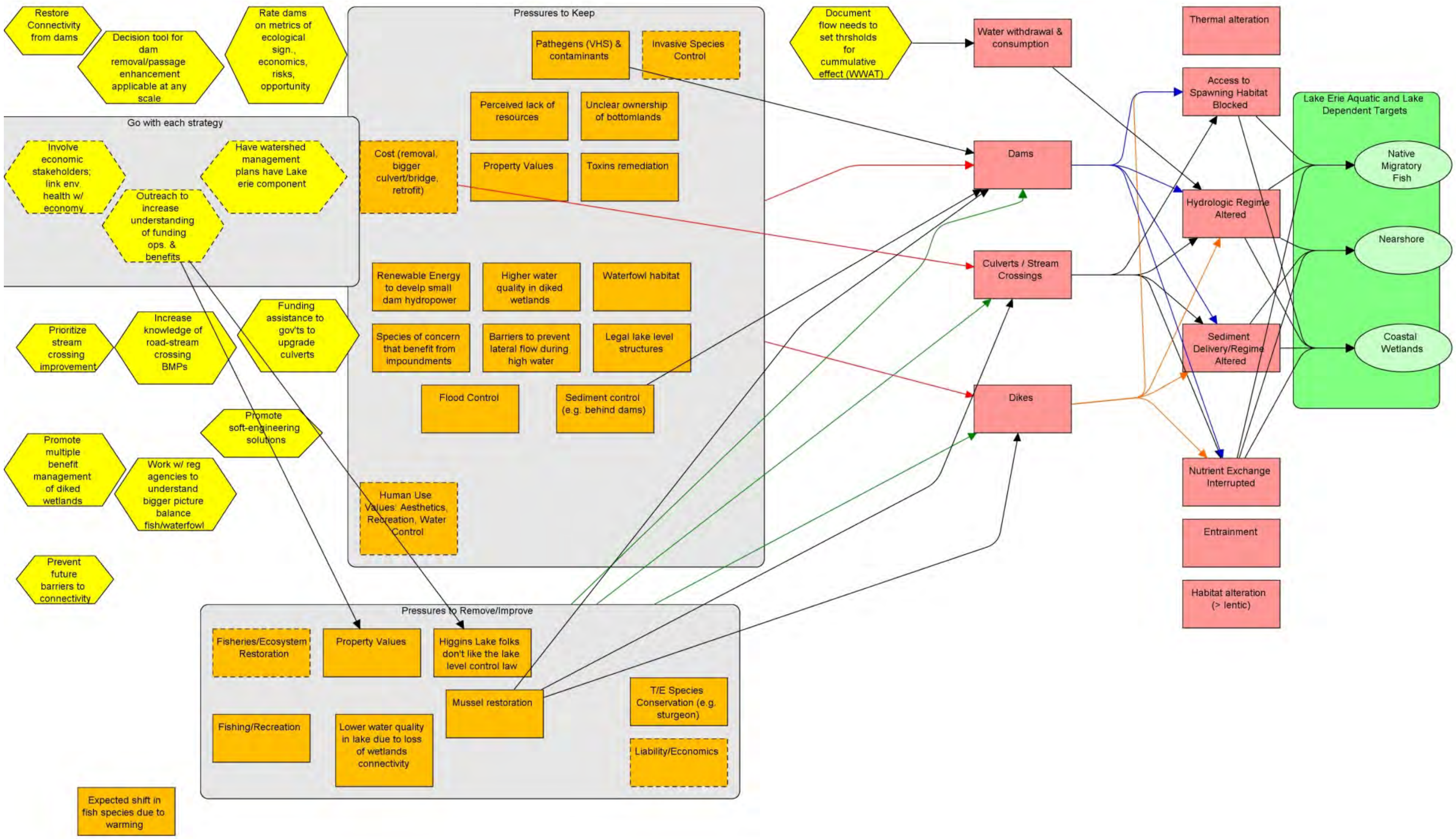

Figure 43: Conceptual model of the dams and barriers threat in Lake Erie.

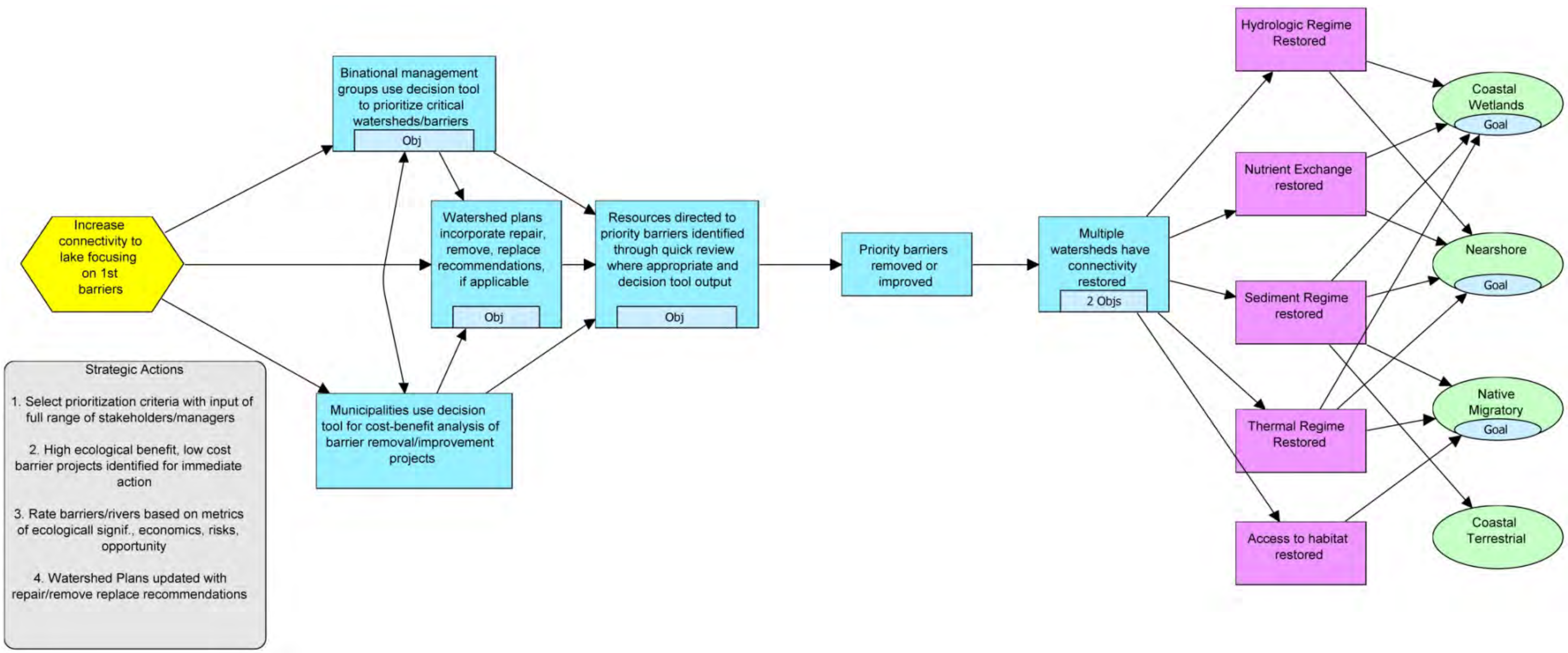

Figure 44: Results chain for increasing connectivity in Lake Erie.

Likely participating agencies and organizations

US Fish and Wildlife Service, U.S. Geological Survey, The Nature Conservancy, Ontario Ministry of Natural Resources, Conservation Authorities in Lake Erie basin (Ontario), state departments of natural resources (U.S.), tribes/first nations.

7. SPATIAL PRIORITIZATION OF CONSERVATION ACTIONS

7.1. Introduction

Earlier in this report, we evaluated the viability of certain biodiversity indicators at the assessment and reporting unit scales for Lake Erie. Although these analyses provide an overall assessment of the health of system targets, the units of analysis are too large to inform conservation action at the local scale. Effective biodiversity conservation requires the identification of priority areas to focus limited resources (Margules and Pressey 2000).

The purpose of the ecological significance analysis is to evaluate the importance of specific coastal areas and islands in Lake Erie for the conservation of biodiversity[28]. These areas are rated based on two primary factors: 1) biodiversity significance, and 2) condition. A set of indicators (similar to the viability assessment located earlier in the report) were scored and added together to calculate an overall index for each factor (biodiversity significance and condition) for two conservation targets (Coastal Terrestrial and Coastal Wetlands).

The same analysis was not applied to the remaining five targets: Open Water, Nearshore, Connecting Channels, and Native Migratory Fish, Aerial Migrants, and Islands. The Open Water target is limited by threats that cannot be addressed through place-based conservation action. The Nearshore and Native Migratory Fish targets are both appropriate for place-based conservation, however the data needed to evaluate these targets is insufficient for identifying important areas. We recognize that a comprehensive classification and mapping of the Nearshore Zone and aquatic species distributions are key data gaps that are high priorities for future research.

The Aerial Migrants target was addressed using methodology developed by Ewert et al. (2012 draft) to model and assess migratory bird stopover sites. Although the final results of this analysis were not available prior to publishing this report, the draft results are briefly discussed. For the Islands target, we used the results from a recent study to assess the biodiversity value of all Great Lakes islands. A quick summary of the results for Lake Erie and the Connecting Channels from this study are presented in this chapter.

[28] The biodiversity significance analysis does not 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.

7.2. Coastal Terrestrial System

7.2.1. Description

An analysis of biodiversity significance was completed for each coastal watershed unit[29] to evaluate the importance of each unit in harboring elements of biological diversity. This process essentially identifies units of biological hotspots, or areas that contain a relatively high proportion of unique plants, animals, and natural communities that have an affinity for the Lake Erie coastal terrestrial environment. Biodiversity significance was measured by the following five factors: 1) coastal shoreline complexity, 2) richness of globally rare terrestrial species (G1-G3), 3) richness of globally rare terrestrial communities (G1-G3), 4) richness of Coastal Terrestrial System types, and 5) frequency of globally rare terrestrial occurrences (plants, animals, and communities). The scores from each of the five factors were summed to produce an aggregated biodiversity score for each unit.

Table 21: Indicators of Coastal Terrestrial biodiversity significance.

Assessment Type	0	1	2	3	4	5	6	7
Coastal shoreline complexity	1	1-1.2	1.2-1.4	1.4-1.8	1.8-2.6	2.6-4	4-5	>5
Richness of globally rare terrestrial species (G1-G3)	0	1	2	3	4	5	6	7+
Richness of globally rare terrestrial communities (G1-G3)	0	1	2	3	4	5	6	7+
Richness of coastal terrestrial system types	0	1	2	3	4	5	6	7+
Frequency of globally rare terrestrial occurrences (G1-G3)	0	1	2	4	8	16	24	32

The condition analysis was meant to reflect the vulnerability of Coastal Terrestrial systems within each coastal watershed unit to immediate changes due to land use activities. Units in good condition contain and are surrounded by areas with relatively low human impact, while units with high human impact in the form of buildings, roads, agriculture, and fragmentation are in poorer condition. Factors used to measure condition included: 1) percent natural shoreline, 2) percent natural land cover within 2 km of shoreline, 3) percent natural land cover within 2-5 km of shoreline, 4) road density within 2 km of shoreline, 5) building density within 500 meters of shoreline, and 6) number of structures perpendicular to the shoreline (piers, jetties, groins) per 100 km. The scores from each of the six factors were summed to produce an aggregated terrestrial condition score for each unit.

[29] Coastal watershed units – smaller units than assessment units; based on coastal subwatershed boundaries. Several small coastal subwatersheds were combined to minimize variation in the size of units

Table 22: Indicators of Coastal Terrestrial condition.

Assessment Type	0	1	2	3	4	5	6	7
Percent natural shoreline	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Percent natural landcover within 2 km of shoreline	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Percent natural landcover within 2-5 km shoreline	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Road density within 2 km of shoreline	>3000	2000-3000	1500-2000	1250-1500	1000-1250	500-1000	250-500	<250
Building density within 500 m of shoreline/km^2	>300	200-300	150-200	100-150	50-100	25-50	10-25	<10
Number of bedload traps and groins/100 km	>300	250-300	200-250	150-200	100-150	30-100	0-30	0

7.2.2. Results

The Coastal Terrestrial biodiversity scores ranged from 3 to 17 out of a possible 35 points, with a mean score of 8. The Rondeau Point coastal watershed unit (unit 34 in Figure 45), located on the Canadian side of the Central Basin received the highest score. Other units that fell into the very high category included: Lower Portage River (31) and Cedar Creek (33), both located in the Ohio portion of the Western Basin; Canard River (18) on the Ontario side of the Detroit River; Lake Erie North (42) on the Ontario side of the Eastern Basin; and South Otter Creek (40) located in the Ontario portion of the Central Basin just west of Long Point.

The Coastal Terrestrial condition scores ranged from 6 to 24 out of a possible 42 points, with a mean score of 15.4. The seven units with the highest scores were all located in Canada (Figure 46). The Tyrconnell Creek unit (27) located in the Central Basin received the highest score. Other top scoring units included the Lake St. Clair Tributaries unit (9) located in the northeast corner of Lake St. Clair, and the Lower Grand River unit (22) located in the Eastern Basin.

The results of the biodiversity significance and condition analyses can be combined to identify coastal watershed units with high biodiversity significance that are under threat and likely to have restoration needs, as well as areas with high biodiversity significance that have relatively fewer factors threatening biodiversity features. Only two of the units with high terrestrial biodiversity scores, Rondeau Point and South Otter Creek, also had relatively high terrestrial condition scores. Although this result is somewhat alarming, it should not be surprising given the amount of land transformation that has occurred in the Lake Erie Basin over the past two centuries. The only unit with high biodiversity values and low condition scores is the Canard River unit (unit 18), located on the Ontario side of the Detroit River, which appears to have high potential for ecological restoration.

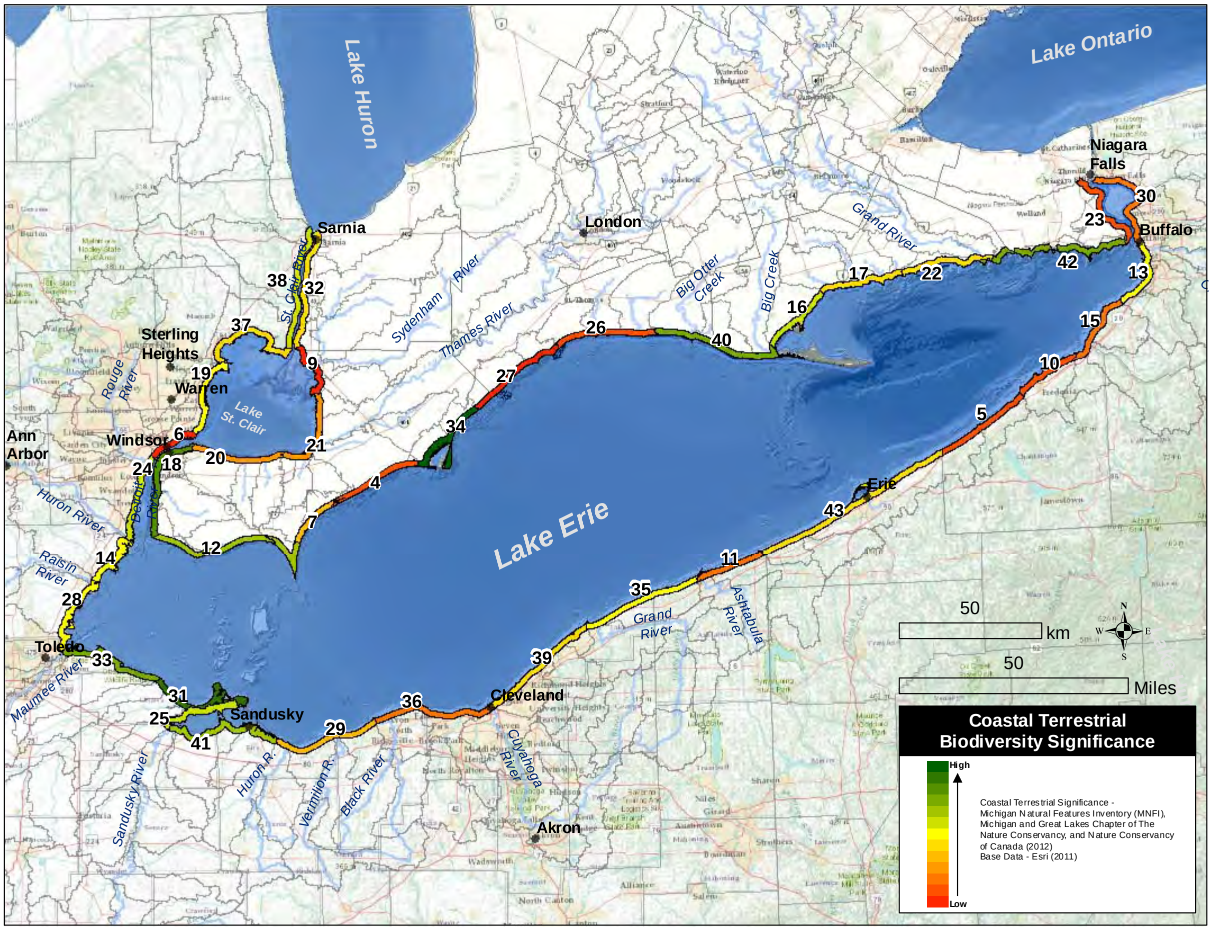

Figure 45: Coastal Terrestrial biodiversity significance.

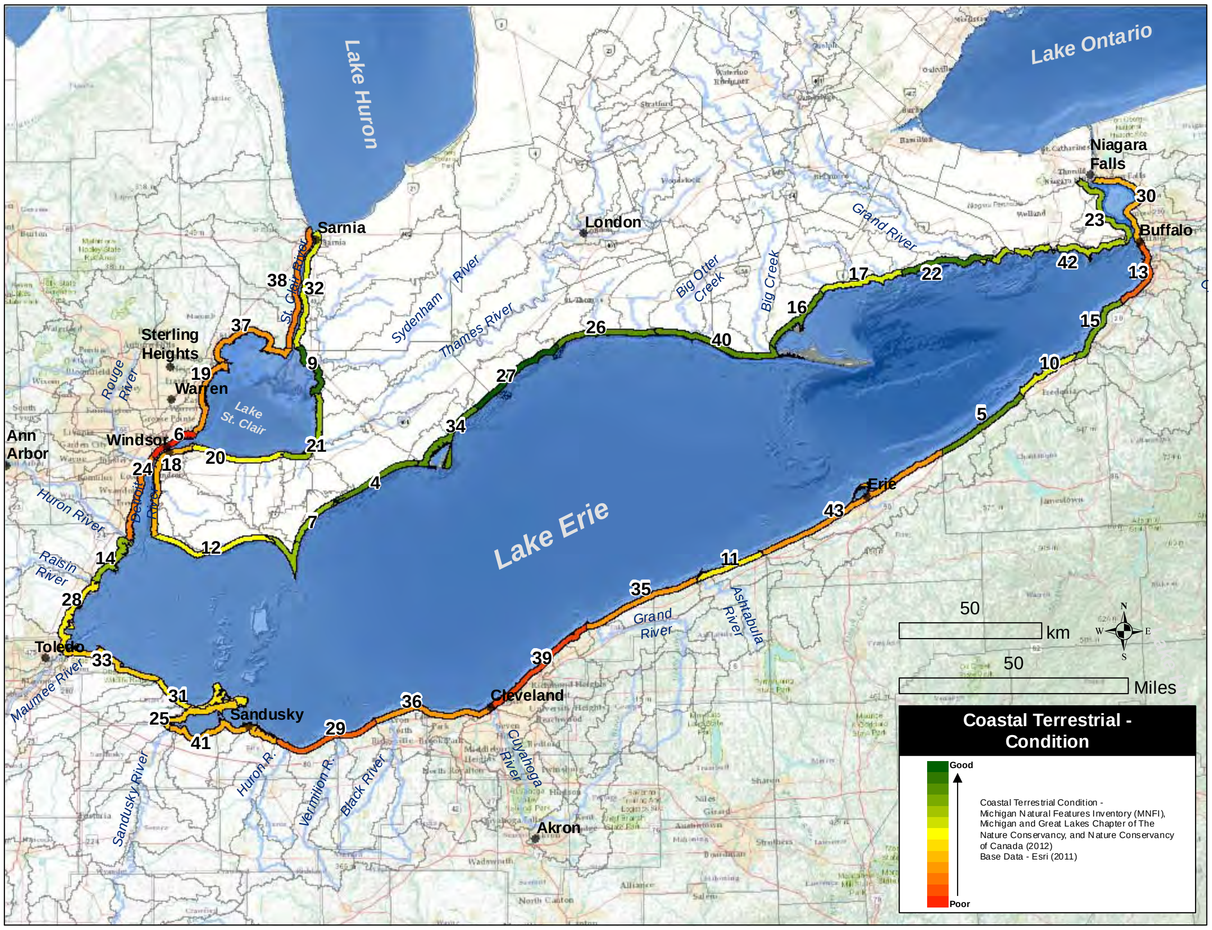

Figure 46: Condition of Coastal Terrestrial Systems

7.3. Coastal Wetlands

7.3.1. Description

An analysis of biodiversity significance was completed for each coastal watershed unit to evaluate the importance of each unit in harboring elements of biological diversity. This process essentially identifies units of biological hotspots, or areas that contain a relatively high proportion of unique plants, animals, and natural communities that have an affinity for Lake Erie Coastal Wetlands. Biodiversity significance was measured by the following five factors: 1) coastal wetland area, 2) richness of globally rare wetland species, 3) richness of globally rare wetland communities, 4) richness of coastal wetland types, and 5) frequency of globally rare wetland occurrences. Similar to the analysis for the Coastal Terrestrial target, the scores from each of the five factors were summed to produce an aggregated Coastal Wetland biodiversity score for each unit.

The condition analysis was meant to reflect the vulnerability of Coastal Wetlands within each coastal watershed unit to immediate changes due to land use activities. Coastal watershed units in good condition contain and are surrounded by areas with relatively low human impact, while units with high human impact in the form of buildings, roads, agriculture, and fragmentation are in poorer condition. Factors used to measure condition included: 1) percent natural land cover within the contributing watershed, and 2) percent natural land cover within 500 meters of each coastal wetland in the unit. The scores from these two factors were summed to produce an aggregated wetland condition score for each unit.

Table 23: Indicators of Coastal Wetland biodiversity significance

Assessment Type	0	1	2	3	4	5	6	7
Percent of coastal wetland area	0	1-5%	5-10%	10-20%	20-30%	30-40%	40-60%	>60%
Richness of globally rare wetland species (G1-G3)	0	1	2	3	4	5	6	7+
Richness of globally rare wetland communities (G1-G3)	0	1	2	3	4	5	6	7+
Richness of coastal wetland types	0	1	2	3	4	5	6	7+
Frequency of globally rare terrestrial occurrences (G1-G3)	0	1	2	3	4	5	6	7+

Table 24: Indicators of Coastal Wetland condition

Assessment Type	0	1	2	3	4	5	6	7
Percent of natural landcover within watershed	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Percent of natural landcover within 500m of coastal wetlands	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%

7.3.2. Results

The scores for the Coastal Wetland biodiversity analysis ranged from 0 to 17 out of a possible 35 points, with a mean score of 4.7. The highest scoring units were Cedar Creek (unit 33) and Pickerel Creek (41) located in the Ohio portion of the Western Basin, and the Swan Creek unit (37) located on the northwest portion of Lake St. Clair in Michigan (Figure 47).

The wetland condition scores for Lake Erie ranged from 0 to 7 out of a possible 14 points, with a mean score of 1.65. Units with the highest scores were Mill Creek/Black River (38) and Swan Creek (37), both located in Michigan within the Huron-Erie Corridor. However, the Mill Creek/Black River unit only contains 610 acres of coastal wetland (only 2.76% of the unit), so the high score is somewhat misleading.

Similar to the Coastal Terrestrial analysis, the results of the biodiversity significance and condition analyses for Coastal Wetlands can be combined to identify coastal watershed units with high Coastal Wetland biodiversity significance that are under threat and likely to have restoration needs, as well as areas with high biodiversity significance that have relatively fewer factors threatening biodiversity features.

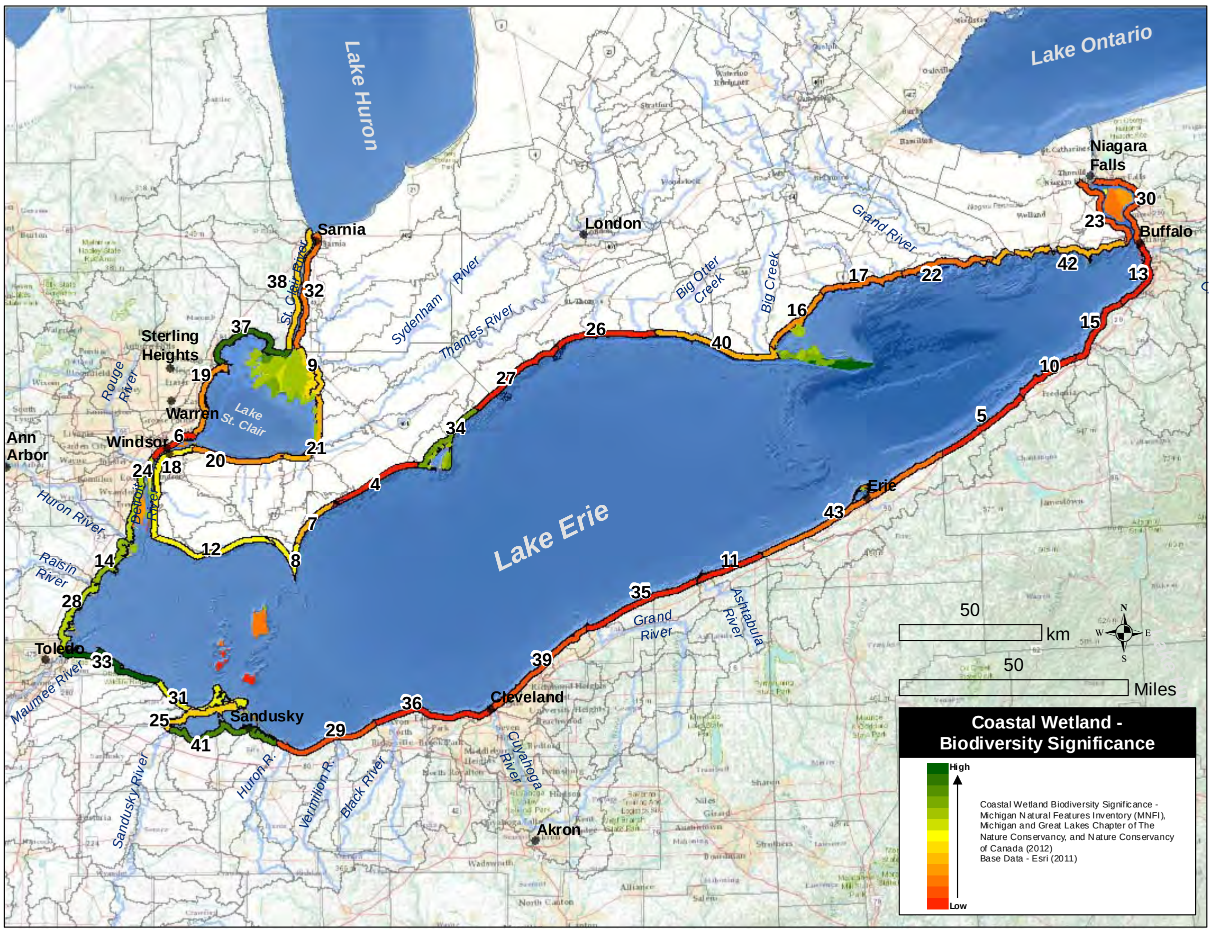

Figure 47: Significance of Coastal Wetlands

The Swan Creek unit (37) in Anchor Bay was the only unit to score relatively high for both biodiversity value and condition. However, this unit has relatively high building and road density as well as one of the highest percentages of artificial shorelines in Lake Erie. These factors were not considered as part of the wetland condition assessment. In addition, it only got a condition score of 4 out of 14, so the fact that it was the second highest scoring unit for wetland condition is a bit misleading. Both the Cedar Creek and Pickerel Creek units (33 and 41, respectively) in Ohio had high biodiversity scores but very low condition scores. These units are located along the southern shoreline of the Western Basin, a region that has undergone a high degree of human settlement and land alteration. These two units may be good areas to employ wetland mitigation strategies to protect the existing resources from further degradation.

Due to the importance of Coastal Wetlands located on islands in Lake Erie, an analysis was also run to evaluate the biodiversity significance of Coastal Wetlands on islands, using the same criteria as for the coastal watershed units. Due to the fact that these islands are much smaller than the coastal watershed units, the thresholds for percent wetland coverage were modified. The island complex with the highest wetland biodiversity significance score is the Long Point wetland complex located on the western most side of the Eastern Basin in Ontario (Figure 47). This series of sand spit islands extends 33 km into Lake Erie, contains over 2,500 hectares of wetlands and harbors a large number of wetland types and species. Other high scoring islands include Dickinson Island, Johnston Channel Island Complex, and Bassett Island, all located in the St. Clair Flats delta of Lake St. Clair. Islands in other areas of the Lake Erie that also scored well include Stony Island in the Detroit River, Point Mouillee in the Western Basin, Presque Isle just outside of Erie, Pennsylvania, Turkey Point just east of Long Point in Ontario, and the Point Aux Pins Island Complex in Rondeau Bay Ontario.

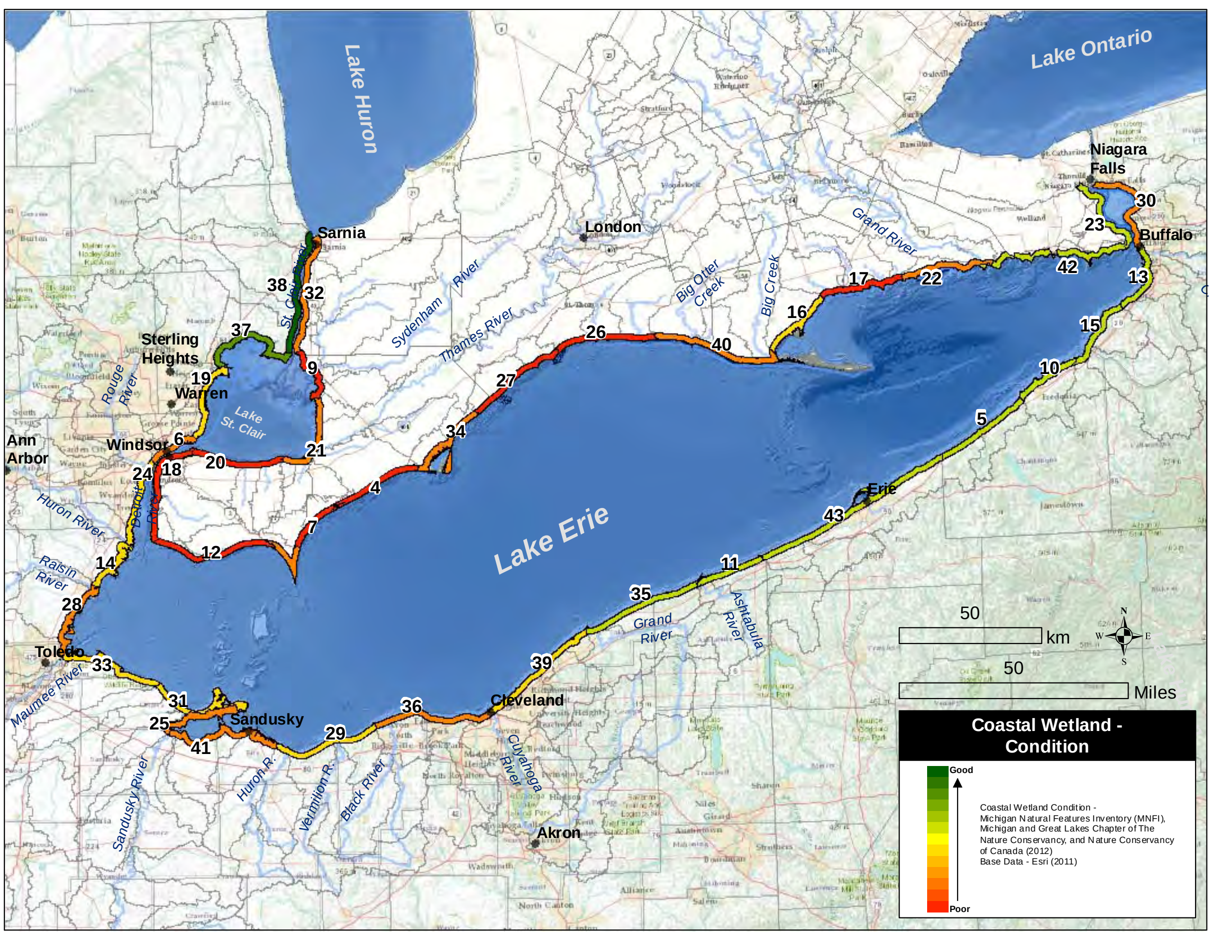

Figure 48: Condition of Coastal Wetlands.

7.4. Islands

7.4.1. Description

The identification of priority Islands was based on the existing binational analysis completed for the Great Lakes Basin (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. According to Henson et al., there are 1,173 islands in Lake Erie (including the upper Niagara River) and 403 islands in the St. Clair-Detroit River connecting channel for a total of 1,576 islands in the Lake Erie Basin.

Lake Erie islands and island complexes were scored based on a suite of criteria to determine their associated conservation value by assigning each island or islands complex a total biodiversity score. Many of the biodiversity scoring criteria were based on the previous work of Ewert et al. (2004). A total of 27 variables were utilized to assess each island or island complex. Major categories of the island biodiversity scoring criteria included: 1) biological diversity, 2) plant communities, 3) ecological systems, and 4) ecosystem functions (refer to Henson et al. 2010 for more details).

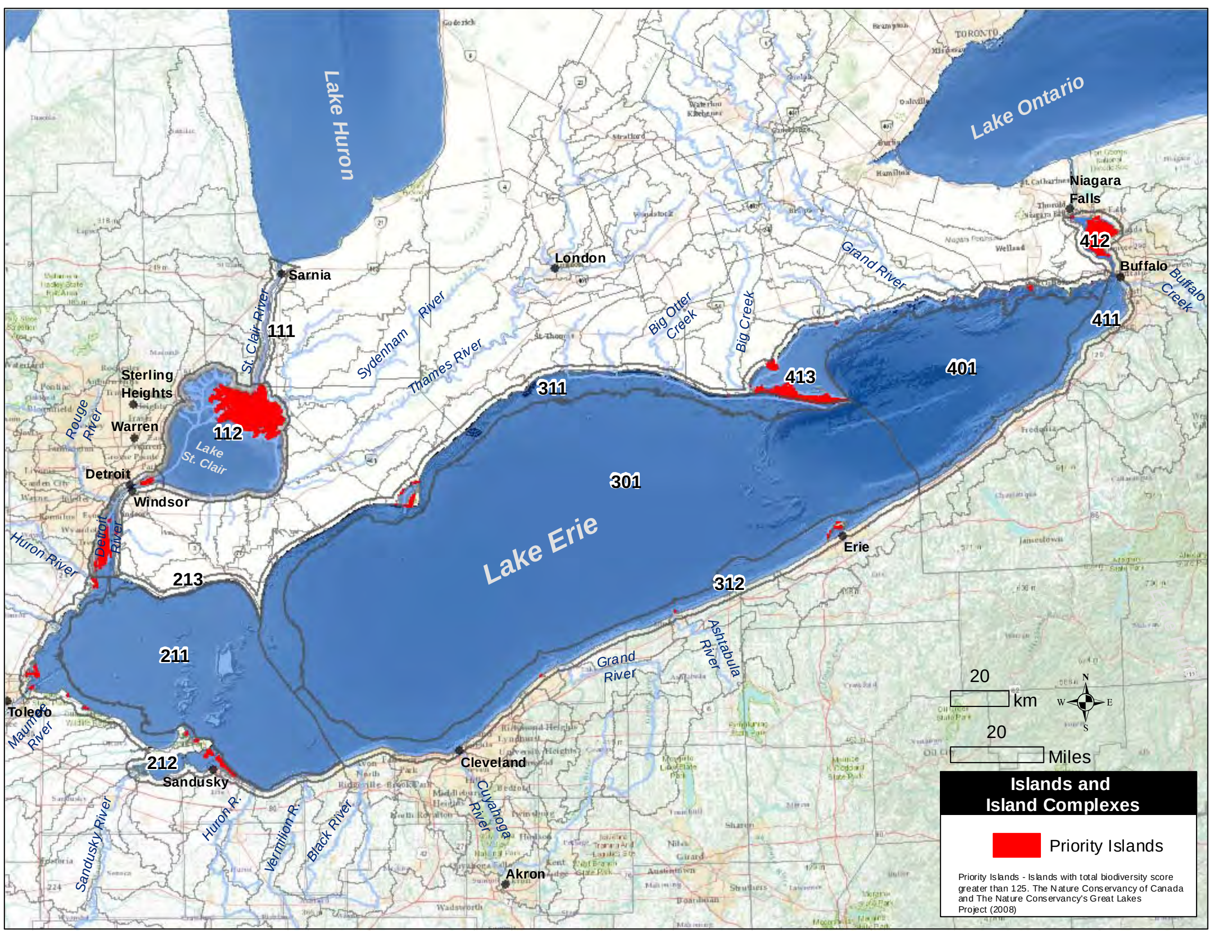

Figure 49: Lake Erie priority Islands.

7.4.2. Results

According to Henson et al. (2010), key islands for biodiversity conservation in Lake Erie include: Pelee Island, Pointe Aux Pins, Long Point, and Turkey Point all located in Ontario, and Kellys Island in Ohio (Figure 49). Key islands in the Huron - Erie Corridor include Harsens Island in Michigan, and Walpole Island, Squirrel Island, St. Anne Island Complex, and Johnston Channel Island Complex all located in Ontario. Grand Island, in the upper Niagara River, was also identified as a priority island.

7.5. Aerial Migrants

7.5.1. Description

As with the Island target, results from an ongoing study were utilized to identify priority areas for Aerial Migrants. The purpose of the study is to model spring migratory bird stopover sites within 25 km of Lakes Ontario, Michigan, Huron, and Michigan, and connecting channels (Ewert et al. 2012 draft). Migratory birds were broken out into three major groups for analysis: 1) landbirds, 2) waterfowl, and 3) shorebirds. Key landscape level attributes were identified, and a GIS model was developed for each group. Some of the factors for evaluating suitable migratory bird stopover habitat were: presence of suitable habitat, proximity to and amount of suitable habitat, proximity to a Great Lake, proximity to a non-Great Lakes waterbody, and patch size. Each attribute was scored individually and then summed to produce an aggregated score for each bird group.

7.5.2. Results

The preliminary results of the modeling study highlight the Western Basin, Huron - Erie Corridor (strong emphasis on the Canadian side), and the Ontario portion of the Eastern Basin as containing significant habitat for both shorebirds and waterfowl during spring migration (see Figure 25 in the description of the Aerial Migrants target.).

8. BIODIVERSITY CONSERVATION AND ECOSYSTEM SERVICES: WILL THESE STRATEGIES BENEFIT PEOPLE?

The primary purpose of the LEBCS is to develop biodiversity conservation strategies for Lake Erie and the surrounding coastal zone. Though the goal of these strategies is to improve the health of and abate the key threats to Lake Erie's terrestrial and aquatic biodiversity, they will undoubtedly affect human well-being. For example, efforts to clean up contaminated nearshore sites to improve fish habitat may also provide better fishing and boating opportunities, increased property values, and improved drinking water quality. Similarly, actions that increase wetland area in the coastal zone move us toward important ecological goals, but also may help protect nearby residents from storm surges that are strengthened by climate change.

To consider the potential benefits to people that may result from implementing the top priority conservation strategies in the Lake Erie coastal area, we employed the concept of ecosystem services, using the framework developed by the Millennium Ecosystem Assessment (2003). The MEA (2003) categorizes ecosystem services into four types, including 1) provisioning services (products, such as food or water, obtained from ecosystems), 2) regulating services (benefits obtained from ecosystem process, such as water purification or climate regulation), 3) cultural services (nonmaterial benefits obtained from ecosystems, such as spiritual, recreational or cultural), and 4) supporting services (services such as soil formation or nutrient cycling that subsequently support all other ecosystem services). Previous assessments of ecosystem services in the Great Lakes are uncommon, and may employ a different framework (e.g., Loucks and Gorman 2004) or focus on smaller geographic areas such as southern Ontario (Wilson [2008], Troy and Bagstad [2009], and Pattison et al. [2011]) and the Chicago area (Kozak et al. 2011). To assess the importance and potential response of ecosystem services to priority conservation strategies, we surveyed a group of over 100 people including project Steering Committee members and experts who had been involved in earlier aspects of this project. Specifically, we sought to: 1) determine the most important ecosystem services provided by the lake and its surrounding coastal zone, and 2) assess the potential impact of the highest priority biodiversity conservation strategies on the most important ecosystem services (as determined in the first phase of the survey).

8.1. Methods

To assess the links between biodiversity conservation and ecosystem services, we first compiled a list of definitions for 32 ecosystem services of the four types described above (MEA 2003), referencing each one to the ecosystem services identified for the Great Lakes by Loucks and Gorman (2004).

To determine how stakeholders value ecosystem services provided by Lake Erie, we next constructed a digital survey using Survey Monkey and invited Lake Erie managers and experts to rate the importance of each ecosystem service to the people that benefit from Lake Erie and its coastal area[30] by assigning each service to one of three importance categories:

1. **Highly important**: this service dramatically improves the quality of life for people who benefit from the lake and its coastal systems, and without this service quality of life is, or would be, significantly degraded, AND/OR this service provides substantial support to commerce or consumer interest associated with Lake Erie;
2. **Moderately Important**: this service moderately improves the quality of life for people who benefit from the lake and its coastal systems and without this service quality of life would be somewhat degraded, AND/OR this service provides moderate support to commerce or consumer interest associated with Lake Erie;
3. **Minimally Important**: this service does little to improve the quality of life for people who benefit from the lake and its coastal systems and without it quality of life is not perceptibly degraded, AND/OR this service provides minimal support to commerce or consumer interest associated with Lake Erie.

We subsequently resurveyed the same audience to assess the potential impact of the highest priority biodiversity conservation strategies—as identified by the LEBCS—on the ten most important ecosystem services identified in the first phase of the survey. Here, we listed each priority strategy and asked participants to estimate the potential effect of the strategy on each of the ten most important ecosystem services as very positive, positive, neutral, negative, or very negative. We also requested that they answer "Don't Know" if they felt unable to provide a particular estimate. We converted the responses to numeric values as follows: very positive = 2; positive = 1; neutral = 0; negative = -1; very negative = -2; and eliminated non-responses and “Don’t Know” values. We then calculated the average effect of each priority strategy on each ecosystem service, and from those values we were able to rank the strategies in terms of their effect on ecosystem services and also, for each ecosystem service, the average cumulative effect across all of the strategies.

8.2. Results and discussion

Fifty six participants, representing all four coastal states and the province of Ontario, completed the first phase of the survey. Federal, State, and Provincial agencies were most strongly represented among survey participants, followed closely by NGO employees (though there were 50% fewer NGO participants in the second survey), and academics (Table25). Notably absent from the survey participants are coastal residents and people who are employed in private commercial or industrial sectors affiliated with Lake Erie.

[30] For the purpose of this assessment, beneficiaries of these services include people who live or work within the coastal area, or those who periodically benefit through use or enjoyment of the lake or its coastal area such as beach-goers, anglers, birders, hunters, boaters, and many others.

Table 25. Participants in the Lake Erie ecosystems services assessment surveys.

Affiliation Category	Phase 1	Phase 2
State/Provincial Agencies	19	12
Federal Agencies	12	12
NGOs	11	5
Academic Institutions	6	5
Municipal Governments	2	
Bi-national Agency (e.g., IJC or Great Lakes Fishery Commission)	1	1
Conservation Authority	1	1
Ecological Consultant	1	1
Heritage Program	1	
Regional Planning Commission	1	
Sea Grant	1	
Grand Total	56	37

To rank the value of specific ecosystem services, we assigned points to each service based on the individual responses: Highly Important – 3 points; Moderately Important – 2 points; Minimally Important – 1 point; and Not Applicable – 0 points. Among the top ten services, the four categories of services are not equally represented; there are four Supporting Services, three Cultural Services, two Regulating Services, and one Provisioning Service. The most fundamental services—Supporting—are best represented in the top ten, while Provisioning services, which are generally considered the most direct benefits to people, are the least well represented (Table 26). Cultural services, such as recreation and aesthetics, are also well represented, possibly reflecting a rich history of and deep connection to the natural resources of the region.

The ten highest ranked ecosystem services for Lake Erie were also the top ten in an identical assessment for Lake Michigan, completed as part of the Lake Michigan Biodiversity Conservation Strategy, though the order of ranking differed among the top ten (Pearsall et al. 2012). There was some overlap between the two sets of contributors—8 of the 56 people (14.3%) who completed the Lake Erie survey also completed the first survey for Lake Michigan—but that amount of commonality is not likely to be a significant factor explaining the highly similar result. A more likely explanation is that the majority of participants in surveys for both lakes were employees of public agencies or NGOs that play some role in managing or conserving the lakes, so it could be said that they represent a relatively narrow range of perspectives.

Thirty seven participants, from all five states in the watershed and the province of Ontario representing Federal (US and Canadian), State and Provincial agencies, as well as private conservation organizations and consulting firms, completed the second phase of the survey aimed at assessing the potential impact of the highest priority biodiversity conservation strategies on the most important ecosystem services.

Table 26. Ten highest ranked ecosystem services, based on a survey of people engaged in conservation and management of Lake Erie (see Appendix J for the full list of ecosystem services, scores and ranks).

Rank	Service	Score
1	Cultural Services - Recreation and tourism (Lake recreation, wild game, song birds, other wildlife)	163
2	Supporting Services - Provision of habitat (Biodiversity support, habitat diversity)	163
3	Provisioning Services - Fresh Water (Water supply)	162
4	Supporting Services - Primary production (Energy capture, food chain support, energy flow for fish, benthic food chain)	159
5	Cultural Services - Aesthetic values (Aesthetics)	156
6	Supporting Services - Nutrient cycling (Nutrient storage)	152
7	Regulating Services - Water purification and waste treatment (Water quality, waste assimilation, groundwater quality)	151
8	Cultural Services - Sense of place	143
9	Supporting Services - Water cycling (Soil moisture storage)	143
10	Regulating Services - Climate regulation (Carbon storage, moderation of weather extremes)	140

The average effect of strategies on ecosystem services ranged from nearly very positive (1.74) to almost neutral (Table 27). On average three sets of strategies (Ag NPS, urban NPS, and coastal conservation, in that order), had the greatest estimated effect across all ecosystem services (Table 23). These three strategies were also predicted to be the most beneficial to ecosystem services in Lake Michigan (Pearsall et al., 2012), suggesting that watershed and coastal strategies could be very rewarding with respect to benefits derived from the lake. Strategies to prevent and reduce threats from terrestrial invasive species were predicted to have the least beneficial effects across all ecosystem services relative to the other focal strategies.

Among all ecosystem services, provision of habitat (supporting service), recreation and tourism, and aesthetic values (both cultural services) were predicted to benefit the most from the biodiversity conservation strategies. Provision of habitat and recreation and tourism bot registered strong positive effects from all the strategies, while aesthetic values were expected to increase somewhat less due to connectivity improvements and invasive species strategies. Climate regulation (regulating service) and water cycling (supporting service) were benefit only slightly from the conservation strategies.

The finding that reducing non-point sources of pollution would result in the greatest potential positive effects on ecosystem services may reflect a burgeoning recognition that some of the greatest challenges facing Lake Erie (such as high or very high concentrations of soluble reactive phosphorus (SRP) and harmful algal blooms) are caused by non-point source pollutants, especially from agricultural sources in the Western Basin. Ongoing work by the IJC to articulate a “Lake Erie Ecosystem Priority” is focused on SRP; the Lake Erie LaMP has developed a nutrient management strategy that highlights this same issue; and several state and provincial agencies have developed strategies or initiatives to reduce nutrients or SRP specifically (see strategies for reducing non-point pollutants from agricultural and urban points sources in Chapter 5 for many more examples). Survey participants likely realized that strategies to abate non-point source pollutants would lead directly or indirectly to many other benefits.

Our ecosystem services survey was designed as an initial assessment of the values that society derives from the Great Lakes and a subsequent assessment of the link between our biodiversity conservation strategies in benefiting ecosystem services. Our survey results provide some general patterns that can help guide future ecosystem service research. First, the top ten ecosystem services ranked by stakeholders contributing to the Lake Erie Biodiversity Conservation Strategy included services from each of the four categories – provisioning, regulating, cultural and supporting – indicating that Lake Erie provides a broad variety of values to these stakeholders. The top ten ranked services for Lake Erie were identical to the top ten for Lake Michigan, although the order varied (Pearsall et al. 2012).

While ranking the potential value of ecosystem services is a valuable first step, our survey also attempted to make a link between our proposed conservation strategies and the subsequent benefit to these services. Our results indicate that Ag NPS, Urban NPS, and Coastal Conservation strategies have the potential to have the greatest benefit to the services ranked highest by our stakeholders. This finding may be a result of the fact that these strategies, if successfully implemented, benefit a broad range of natural features that are concentrated along coastal areas where society derives much value from ecosystems.

While preliminary, the concordance of our results across two lake basins, Erie and Michigan, provide some insight into the values derived from the lakes. Additionally, there exists the potential to be strong ecosystem service benefits from our proposed conservation strategies. Our hope is that this initial survey will provide a base for further ecosystem service research and that these values become a common component of future conservation planning, management and outcome measures.

Table 27. Average estimated effect of priority biodiversity conservation strategies on the ten most important ecosystem services in Lake Erie. Cells are shaded to represent a gradient from dark red (least positive, or negative) to dark green (most positive) effect. Strategies are abbreviated: AgNPS = Reducing the impacts from agricultural non-point source pollutants; InvTerr and InvAqua = preventing and reducing the impact of invasive species (terrestrial and aquatic, respectively); Coastal = Coastal conservation: reducing the impact of housing and urban development and shoreline alteration; UrbanNPS = reducing the impact of urban non-point and point source pollutants; and Connectivity = improving connectivity for streams fragmented by dams and barriers. See Appendix J for a key to ecosystem service abbreviations.

	Strategies						
Ecosystem Services	AgNPS	InvTerr	InvAqua	Coastal	UrbanNPS	Connectivity	Average response of ecosystem service across all strategies
Cultural Services - Aesthetic values (Aesthetics)	1.28	1.00	0.89	1.53	1.34	0.89	1.15
Cultural Services - Recreation and tourism (Lake recreation, wild game, song birds, other wildlife)	1.56	1.13	1.58	1.58	1.16	1.11	1.35
Cultural Services - Sense of place	0.56	0.67	0.60	1.32	1.03	0.70	0.81
Provisioning Services - Fresh Water (Water supply)	1.43	0.20	0.44	0.53	1.36	0.42	0.73
Regulating Services - Climate regulation (Carbon storage, moderation of weather extremes)	0.35	0.06	0.15	0.54	0.45	0.06	0.27
Regulating Services - Water purification and waste treatment (Water quality, waste assimilation, groundwater quality)	1.46	0.26	0.61	0.66	1.45	0.49	0.82
Supporting Services - Provision of habitat (Biodiversity support, habitat diversity)	1.38	1.74	1.68	1.74	1.13	1.55	1.54
Supporting Services - Nutrient cycling (Nutrient storage)	1.62	0.35	0.62	0.89	1.08	0.59	0.86
Supporting Services - Primary production (Energy capture, food chain support, energy flow for fish, benthic food chain)	1.26	0.88	1.32	0.89	0.94	0.92	1.04
Supporting Services - Water cycling (Soil moisture storage)	0.76	0.19	0.13	0.67	0.94	0.30	0.50
Average effect of strategy across all ecosystem services	1.17	0.65	0.80	1.03	1.09	0.70	0.91

9. IMPLEMENTING THE BIODIVERSITY CONSERVATION STRATEGY: RECOMMENDATIONS FOR A COLLABORATIVE ADAPTIVE APPROACH

"Coming together is a beginning. Keeping together is progress. Working together is success."
Henry Ford

9.1. Introduction

The LEBCS presents key components of a common vision for the conservation of Lake Erie biodiversity. The strategies (with associated goals, objectives and measures) are designed to augment efforts to fulfill obligations of the Great Lakes Water Quality Agreement (GLWQA) as updated in 1987 and 2012, the Great Lakes Restoration Action Plan, and a host of other local and regional priorities (see Appendix K). In this brief chapter, we put forward several general recommendations to facilitate implementation of the LEBCS based on the experience of TNC and its partners implementing biodiversity conservation strategies for Lake Ontario and Lake Huron, as well as important insights and suggestions from the project Steering Committee and a diverse collection of regional stakeholders. These recommendations focus on organizational structure and enhancing community engagement, developing an implementation plan and a process to conduct adaptive management, and finally, aligning EPA funding streams to achieve LaMP priority outcomes.

9.2. Recommendations

9.2.1. LAMP adopts LEBCS and affirms a common vision and priorities

For the strategies in the LEBCS to be successfully implemented, it is critical that the Lake Erie LAMP adopt the LEBCS into the current work plan or, as the Lake Ontario LaMP has done, undergo a planning process to integrate and produce a set of biodiversity conservation strategies based on the LEBCS (Lake Ontario LaMP Work Group and Technical Staff, 2011). This process would be best served to expand stakeholder engagement that can build ownership, support and investments by the greater Lake Erie community in the target outcomes and actions necessary to achieve these goals. In doing so, the LaMP will establish a common vision and priorities for conservation of biodiversity in Lake Erie that has a better chance of achieving implementation.

9.2.2. Organizational structure and assembling your team

Successful implementation of projects, programs or strategies requires that the organizational structure fit the purpose, goals and outcomes of the strategy as well as the skillsets, roles and responsibilities of the team charged with implementation. A private business may enjoy neater processes than a public agency or a collaborative body engaged in managing a complex, multi-jurisdictional, public natural resource, but the concept question prevails: Is the lead entity and implementation team (EPA-GLNPO, Environment Canada, and the Lake Erie LaMP) organized and structured appropriately to successfully implement and achieve the goals and outcomes of the strategy or will it require restructuring? Some important attributes of successful organizational structures include:

- A "backbone" organization (*sensu* Kania and Kramer 2011) and appropriate staff with the necessary authority (decision maker) to effectively lead, coordinate, and manage the implementation of the strategies. Many of the strategies in the LEBCS build on the efforts and authorities of existing entities and programs; however, progress on this ambitious agenda will require close coordination to track progress, re-prioritize as progress is made, facilitate collaboration, reduce duplication of efforts, and keep momentum for implementing the LEBCS.

- An analysis of optimal structure. To determine the optimal structural approach will require thoughtful analysis and is beyond the scope of this project, but we recommend the analysis be undertaken. Is one large basin-wide organization the most effective means of organizing geographic and issue related strategies? Or should the approach break the basin into smaller teams working on strategies specific to their geography that require local solutions (e.g., Urban and Rural Non-point Source Pollution) augmented by issue-based, basin-wide teams that can employ broad intervention (e.g., Aquatic Invasive Species)?

- Expand stakeholder engagement to include corporate and industrial sectors, as well as local-regional government.

    - Build support and participation from within the private sector, most particularly those that have the greatest influence on and are integral to the success of the priority strategies identified in the LEBCS based on their own actions and their ability to influence others.

    - Build support and participation among local and regional elected officials to identify points of alignment and areas that fall within their jurisdiction and responsibility and are integral to the success of the priority strategies identified in the LEBCS.

A working example of a collaborative effort with such "backbone" organizations and dynamic boards of directors and steering committees include the dual designation of the Detroit River as Heritage Rivers in both the US (Greater Detroit American Heritage River) and Canada (Detroit River: a Canadian Heritage River).

9.2.3. Develop an implementation plan, and employ an adaptive management approach

Successfully implementing the biodiversity conservation recommendations in the LEBCS will require that leaders, decision makers and stakeholders around the Lake Erie basin adopt a common vision and agenda, and then develop an Implementation Plan comprising a work plan with specific action steps that will result in achievement of the goals and objectives, and assigned team leaders and associated members to fulfill action steps. Implementation will be bolstered by regular communications internal to the organization as well as external to the community and stakeholders, all with the continuous support from a 'backbone' organization to drive action and accountability, as well as facilitate communications and sustained momentum (Kania and Kramer 2011).

Equally important, the LEBCS should be viewed as a living document and be regularly updated using adaptive management as a standard component of the review, analysis and business planning processes. Adaptive Management has been defined as:

> *"The incorporation of a formal learning process into conservation action. Specifically, it is the integration of project design, management, and monitoring, to provide a framework to systematically test assumptions, promote learning, and supply timely information for management decisions.AM is a deliberate process, not ad-hoc or simply reactionary. However, flexibility in the approach is important to allow the creativity that is crucial to dealing with uncertainty and change." (Conservation Measures Partnership, 2007)*

The 2012 GLWQA will require LaMPs to update plans on a five-year cycle for reporting and revisions, but will initiate the cycle with status updates and modifications to the work plan to be updated by 2013, then to resume the five-year cycle. Adaptive management should be incorporated into this reporting and revisions cycle, but should also not be restricted to this cycle. Adaptive Management provides a framework for revisiting, revising, and reaffirming commitments to the highest priority actions needed in a system, however it also provided an avenue for ramping up successful strategies to take advantage of windows of opportunity or instigate course corrections based on policy or priority changes, as well as underperforming approaches.

Specific recommendations include:

- Revise the work plan in the Lake Erie LaMP 2008 update to include specific actions to fulfill the common vision and priorities with benchmarks, measures and outcomes as well as accountability for achieving outcomes.

- Include an adaptive management approach to both the work plan and the five-year revision cycle. The adaptive management approach assumes natural resource management policies and actions are not static but adjusted based on the combination of new scientific and socio-economic information in order to improve management by learning from the ecosystems being affected.

9.2.4. Align funding streams to achieve LaMP priority outcomes

Federal funding in the U.S. and Canada has been in a pattern of decline overall, while the Great Lakes have enjoyed several years of concentrated increases thanks to the Great Lakes Restoration Initiative on the US side, and in coming years through the Great Lakes Nutrient Initiative in Canada. In order to achieve the greatest measurable impact on Great Lakes health for dollars spent, we submit a final recommendation to aligning US EPA and EC funding to achieve LaMP priority outcomes. This includes appropriate funding and staffing of EPA and EC divisions charged with LaMP management, and previous recommendations to more fully engage stakeholders.

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APPENDIX C: DEFINITIONS OF THE CONSERVATION ACTION PLANNING

Acceptable Range of Variation – Key ecological attributes of biodiversity conservation targets naturally vary over time. The acceptable range defines the limits of this variation that constitute the minimum conditions for persistence of the target (note that persistence may still require human management interventions). This concept of an acceptable range of variation establishes the minimum criteria for identifying a conservation target as "conserved" or not. If the attribute lies outside this acceptable range, it is a degraded attribute.

Benefits - The benefits of a given strategic action derive from directly achieving threat and viability objectives (direct benefit) as well as from enabling or catalyzing the implementation of another strategic action (indirect benefit or leverage). Benefits are assesses based on the scope and scale of outcome, contribution to the achievement of the objective, duration of outcome and leverage.

Biodiversity Conservation Targets – 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 biodiversity conservation targets will ensure the conservation of all native biodiversity within functional landscapes. Often referred to as "focal targets", "biodiversity features" or "focal biodiversity."

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.

Cost - Strategic action costs should be estimated for the time horizon of the strategy, but no longer than 10 years. Cost estimates should focus on the use of discretionary or unrestricted dollars (or other appropriate currency). Overall cost is based on the amount of any one-time cots, annual cost, staff time and number of years.

Critical Threats - Sources of stress (direct threats) that are most problematic. Most often, Very High and High rated threats based on the Conservancy's threat rating criteria of their impact on the biodiversity conservation targets.

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 of the target.

Desired Future 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.

Ecosystem services: the benefits people obtain, directly or indirectly, from ecosystems.

Feasibility - Overall feasibility of a strategic action is based on the feasibility to lead individual and institution, the ability to motivate key constituencies and the ease of implementation.

Indicator - 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."

Intermediate Result - A factor in a results chain that describes a specific outcome that results from implementing one or more conservation strategies. In Miradi, an intermediate result is represented by a blue rectangle.

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

Key Ecological Attribute (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 Targets - 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.”

Potential impact:

Results Chain: a tool that clarifies assumptions about how conservation activities are believed to contribute to reducing threats and achieving the conservation of biodiversity or thematic targets. They are diagrams that map out a series of causal statements that link factors in an "if...then" fashion - for example, if a threat is reduced, then a biodiversity target is enhanced or if an opportunity is taken, then a thematic target might be improved. In some organizations, results chains are also termed logic models.

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.

Scope or Project Area - The place where the biodiversity of interest to the project is located.

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).

Situation Analysis: A conceptual model or “picture” of your hypothesized linkages between indirect threats and opportunities, critical threats, and biodiversity conservation targets.

Sources of Stress (Direct Threats) – 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 (e.g., logging).

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.

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.

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).

Target-Threat Rating - The rating of the effect of a direct threat on a specific target. The target-threat rating is calculated using a rule-based system to combine the scope, severity, and irreversibility criteria.

Threat Reduction Result - A factor in a results chain that describes the desired change in a direct threat that results from implementing one or more conservation strategies. In Miradi, a threat reduction result is represented by a purple rectangle.

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.

Viability Ratings - A project's scale of what is *Very Good*, *Good*, *Fair*, or *Poor* for a given indicator for a given target. Viability ratings are often quantitatively defined, but they can be qualitative as well. In effect, by establishing this rating scale, the project team is specifying its assumption as to what constitutes a "conserved" target versus one that is in need of management intervention.

APPENDIX D: STRATIFICATION APPROACH FOR LAKE ERIE BIODIVERSITY CONSERVATION STRATEGY

Reasons to stratify

- To make sense of ecological complexity and variability in a Great Lake. As exemplified in previous large lake plans, viability and threat ratings at the scale of a whole lake don't carry much meaning for people who want to set priorities and implement conservation at more local scales.
- Audience. Because people organize regionally around the lake (based on social and cultural factors, including threats) and identify with particular parts of the lake, we want to use a system that reflects those patterns. Therefore, to the extent that the stratification units can be aggregated across each lake, integrating Coastal, Nearshore, and Offshore, using sub-basins that are recognized by sectors of the public, we can better report out to those groups to make the results of the analyses and strategic priorities more meaningful.

Approach

In this proposed approach, we stratify the lake at two scales: 1) ***Reporting units*** that generally reflect accepted sub-basins within each lake and are largely consistent with the Aquatic Lake Units identified in the Great Lakes Regional Aquatic Gap Analysis (McKenna and Castiglione 2010). To delineate specific boundaries for reporting units, the predominant determinant was lake circulation patterns, since these influence functional processes within the lake and between the lake and coasts. Lake bathymetry was also a significant determinant of reporting unit boundaries. These units will integrate all targets from one side of the lake to the other, except in the case of , which is physically disjunct from the rest of Lake Erie and demands independent reporting; 2) ***Assessment units***, at a finer scale than reporting units, reflect ecological patterns and processes primarily associated with two sets of targets, the Coastal and Nearshore areas and Offshore areas. Patterns and processes that inform the delineation of these units include depth, current, substrate, temperature, large tributary (≥5th order) influences, and Element Occurrence distribution patterns. We are building on familiar frameworks, including the SOLEC Biodiversity Investment Areas (BIAs; Rodriguez and Reid 2001), as modified for TNC's coastal prioritization (TNC 2007); this modification involved clipping the BIAs to a 2 km buffer inland from the coast and to 15 m, the accepted depth that distinguishes Nearshore from Offshore in Lake Erie. These units should serve well for evaluation of viability and threats (for threats that occur within the system targets themselves).

This initial stratification approach suggests four reporting units and thirteen assessment units, nested hierarchically as depicted in Figure 1.

Reporting Units: Lake Erie has been widely recognized to have three distinct basins—western, central, and eastern—that are defined by distinct bathymetry and circulation (Sly 1976 and Lake Erie LaMP 2008). Delineations of the boundaries between these basins, however, vary among agencies. We have chosen to adhere to boundaries that are most consistent with Lake Erie circulation patterns, as determined by Beletsky et al. (1999), and consistent with the Great Lakes Aquatic Gap Analysis Aquatic Lake Units (Figure 2).

Other factors important in determining reporting unit boundaries include significant shoreline features and bathymetry. In addition, the Huron-Erie Corridor (including the St. Clair River, Lake St. Clair, and the Detroit River) is a fourth reporting unit.

Assessment units: Beginning with the reporting units, we evaluated coastal reaches, depth, current, substrate, temperature, and large tributary influences, striving to reduce the number of coastal/nearshore assessment units in each reporting unit to two or three. These coastal/nearshore assessment units include Coastal Terrestrial, Coastal Wetland, and Nearshore targets of all types, including the Connecting Channels of the Detroit, St. Clair, and Niagara Rivers (down to Niagara Falls only).

Challenges: Since lake circulation patterns in the Eastern Basin are highly influenced by Long Point, the circulation patterns in the Eastern basin do not correspond with the bathymetry. This incongruence presents some challenges, but we chose to use the circulation pattern as the major determinant since it is the major functional regime that broadly influences all Lake Erie conservation targets (including Coastal Terrestrial) and define lake units that are functionally inter-related. As a result, the deepest offshore area in Lake Erie is divided between the eastern and Central Basin reporting units from the tip of Long Point to the southern shore. Similarly, Point Pelee is an anchor point for the division between the Western and Central Basin. Both of these peninsulas host very high concentrations of conservation targets on land and in adjacent coastal wetlands, so splitting them down the middle would necessitate dividing many (tens or hundreds) of natural community and species Element Occurrences. To avoid splitting these recognizable coastal features, we shifted the boundary between adjacent assessment units so that the coastal terrestrial portion of each peninsula is entirely in one unit and the nearshore aquatic component in another. There is some overlap between adjacent reporting units as a result, but the spatial integrity of identifiable Coastal Terrestrial and Nearshore features is preserved.

The boundary between the Western and Central Basins presents challenges in that the coastal reaches extend beyond the peninsulas and corresponding chain of islands that represents a bathymetric boundary. However, it is more consistent with circulation patterns, and more closely aligns with the coastal reach boundaries. Also, while this boundary does not follow the island ridge, it does follow a ridge between the Eastern and Western Basins, but as a result leaves some nearshore-open water within the Central Basin. Because this is such a small area, we have included this area within the adjacent coastal assessment units, in recognition that this nearshore habitat will be more similar to these units than the adjacent, deeper, offshore waters.

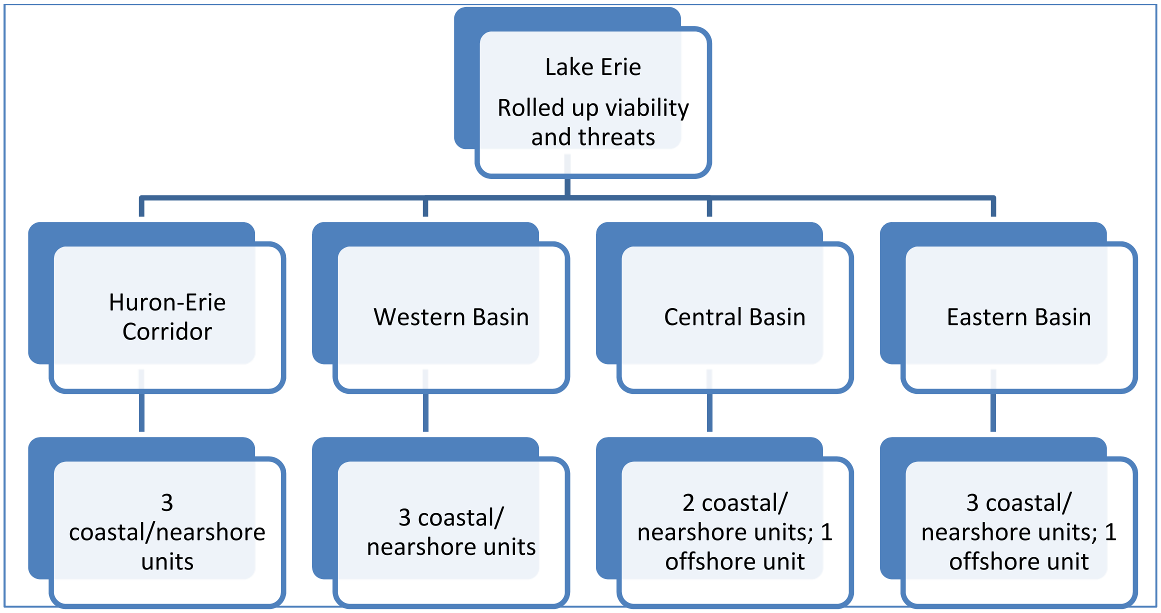

Figure 1. Conceptual diagram of reporting and assessment units in Lake Erie.

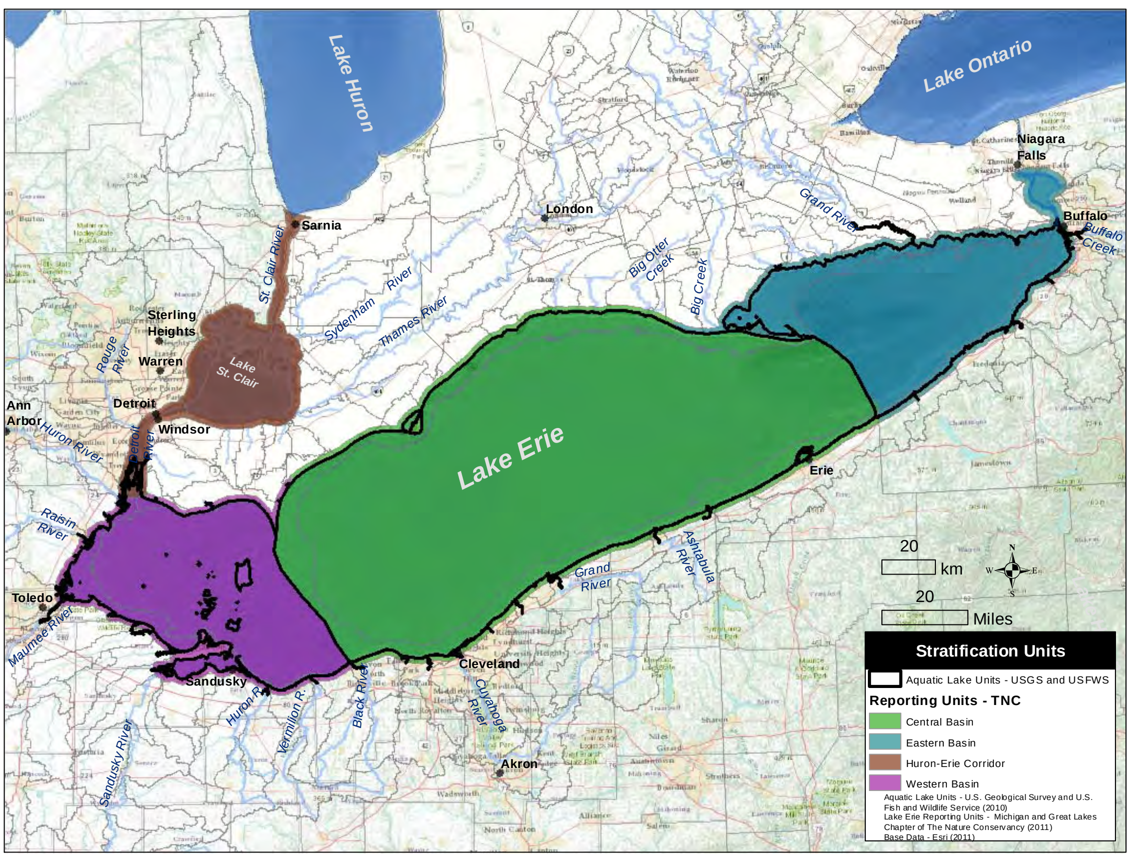

Figure 2: Aquatic Lake Units (ALUs) in Lake Erie McKenna and Castiglione 2010), overlain on LEBCS reporting units. .

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APPENDIX E: VIABILITY OF CONSERVATION TARGETS

In this appendix, we present current status and indicator ratings for all KEAs and indicators for each of the conservation targets. For each target, there are one or several indicators for which we do not have supporting data or information, or for which we have not completed the required analyses. There are some indicators for which the data does not yet exist, but experts have recommended the indicator as important for that target; these indicators represent information gaps that should be pursued by the Lake Erie science community. In the final version of this report, we will provide a summary of those information gaps and priorities for further research.

Legend and KEY to abbreviations:

KEA	Key Ecological Attribute	
SR		Source of Rating
	RG	Rough Guess
	EK	Expert Knowledge
	ER	External Research
	OR	Onsite Research
RU	Reporting Unit (see Appendix D: stratification)	
	HEC	Huron – Erie Corridor
	WB	Western Basin
	CB	Central Basin
	EB	Eastern Basin
AU	Assessment Unit (see Appendix D: Stratification)	
TBD	To be determined	

Colors used to indicate current status:

Poor	(red)
Fair	(yellow)
Good	(light green)
Very Good	(dark green)
NA	Not assessed

Source for current status measure:

RG	Rough Guess
EK	Expert Knowledge
RA	Rapid Assessment
IA	Intensive Assessment
NS	Not Specified

Open Water Benthic and Pelagic Ecosystem

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Competition	Round goby density (mean catch per hectare)	peak level (2001 - 2009)	density less than 10 year average	density half of 10 year average or less	0	RG	CB	301	(IA)
								EB	401	(IA)
Condition	Fish community composition	Species diversity	TBD	TBD	TBD	TBD		CB	301	NA
								EB	401	NA
Condition	Food web linkages	Hexagenia mean density in fine sediments (3 yr average)	<30/ m^2	30-100/ m^2 or >400/ m^2	101-200/ m^2 or 301-400/ m^2	201-300/ m^2		CB	301	(NS)
Condition	Mid-level prey abundance	Alewife density	> 5 kg/ha	0.5-5 kg/ha	0.05-0.5 kg/ha	0.05 kg/ha or less	EK	CB	301	(EK)
								EB	401	(EK)
Condition	Mid-level prey abundance	Prey biomass (currently includes rsmelt, round goby, emerald shiner, gizzard shad (walleye, Central Basin))	TBD	insufficient forage biomass to support top predators	sufficient forage biomass to support top predators (i.e., no growth impediments to top predators)	TBD	EK	CB	301	(EK)
								EB	401	(EK)
Condition	Mid-level prey composition	Proportion native prey in biomass	<25%	25-50%	>50%	predominantly native	EK	CB	301	(RG)
								EB	401	(RG)
Condition	Phytoplankton community structure	% or biomass of mycrosystis, anabena, and aphanizomenon	TBD	TBD	TBD	TBD		CB	301	NA
								EB	401	NA
Condition	Population size & dynamics	5-year trend in lake whitefish abundance	TBD	declining	stable	increasing	EK	CB	301	(RG)
								EB	401	(EK)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Population structure & recruitment	Coregonids: lake whitefish – Growth based on length to width ratio	TBD	TBD	TBD	TBD		CB	301	NA
								EB	401	NA
Condition	Population structure & recruitment	Coregonids: lake whitefish – number of year classes > yr 5 that are well represented (down grade if uneven distribution)	<4	4-6	7-10	>10	EK	CB	301	(IA)
								EB	401	(IA)
Condition	Predator fish species population size	5-year trend in burbot biomass	TBD	declining	stable	increasing	EK	EB	401	(EK)
Condition	Predator fish species population size	Lake trout (catch per unit effort)	<2 fish per net lift	>2-7 fish per net lift	8 fish per net lift	>8 fish per net lift	RG	EB	401	(IA)
Condition	Predator fish species population size	Lake trout recruitment (natural)	no recruitment	some evidence of natural reproduction	clear evidence of natural reproduction	self-sustaining population to historical levels of abundance (from FCOs)	RG	EB	401	(IA)
Condition	Predator fish species population size	Walleye population (number age 2+) - 5-yr average	0-15 million = crisis, 15-20 million = rehabilitation	20-25 million = low quality	25-40 million = maintenance	40 million and higher		CB	301	(NS)
Condition	Predator fish species population size	Yellow perch population (number age 2+) - 5-yr average	<mean 1990-present, declining for >5 years	>mean 1990-present, declining for >5 years	>mean 1990-present, trend stable or showing increase for one of past five years	>mean 1990-present, trend stable to increasing for 5 years		CB	301	(IA)
								EB	401	(NS)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Zooplankton community structure	Ratio of calinoids/(cyclopods + cladocerans)	TBD	TBD	TBD	TBD		CB	301	NA
								EB	401	NA
Landscape Context	Water quality	Benthic Diversity and Abundance	3.0 (polluted)	>1.0 eutrophic	0.6 - 1.0 mesotrophic	<0.6 oligotrophic	EK	CB	301	(EK)
								EB	401	(EK)
Landscape Context	Water quality	Dissolved Oxygen - mean hypolimnetic DO when water column is stratified - frequency distribution of known data	most stations below 4 mg/l	many stations below 4 mg/l	stations mostly above 4 mg/l	all above 4 mg/l	EK	CB	301	(NS)
			most stations below 6 mg/l	many stations below 6 mg/l	stations mostly above 6 mg/l	all above 6 mg/l		EB	401	(IA)
Landscape Context	Water quality	Total Phosphorus concentrations (µg/L)	>20	10 - 20	≤10	TBD	ER	CB	301	(IA)
			TBD	>10				EB	401	(IA)
Landscape Context	Water quality	Water clarity (secchi depth)	TBD	<3 m	3-5 m	TBD	ER	CB	301	(IA)
				<6 m	>= 6 m			EB	401	(IA)

Nearshore Zone

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Community architecture	3-year running average total native intolerant fish species richness in annual bottom trawl surveys	<2	2 - 2.999	3 - 4	>4	ER	HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA
Condition	Community architecture	Mean Dreissena density	>1000 m^{-2}	500-1000 m^{-2}	101-500 m^{-2}	<100 m^{-2}	OR	HEC	112	NA
								WB	211	NA
									212	NA
								WB	213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA
Condition	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	Representative populations meeting goals for relative abundance/ CPUE & remaining populations at >80% of goal	Each representative population meeting goals for relative abundance/ CPUE		HEC	112	NA
								WB	211	NA
								WB	212	NA
								WB	213	NA
								CB	311	NA
								CB	312	NA
								EB	411	NA
								EB	413	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Community architecture	Walleye population (number age 2+)	0-15 million = crisis, 15-20 million = rehabilitation	20-25 million = low quality	25-40 million = maintenance	40 million and higher		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	(NS)
									312	(NS)
								EB	411	NA
									413	NA
Condition	Community architecture	Yellow perch (annual biomass)	<15 million	25 million	50 million	70 million and higher		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA
Condition	Community architecture	Yellow perch population (number age 2+) - 5-yr average	<mean 1990-present, declining for >5 years	>mean 1990-present, declining for >5 years	>mean 1990-present, trend stable or showing increase for one of past five years	>mean 1990-present, trend stable to increasing for 5 years		WB	211	(NS)
									212	(NS)
									213	(NS)
								CB	311	(NS)
									312	(NS)
								EB	411	(NS)
									413	(NS)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Food web linkages	Hexagenia mean density in fine sediments (3 yr average)	<30 / m^2	30-100 / m^2 or >400 / m^2	101-200 / m^2 or 301-400 / m^2	201-300 / m^2		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	(NS)
									312	(NS)
								EB	411	NA
									413	NA
Condition	Food web linkages	Mean densities of rotifers, copepods, and cladocerans in early summer (individuals/L)	Rotifers <100; Copepods <50; Cladocerans <35	Rotifers 100 - 150; Copepods 50 - 75; Cladocerans 35 - 50	Rotifers >150 - 300; Copepods >75 - 125; Cladocerans >50 - 75	Rotifers >300; Copepods >125; Cladocerans >75		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA
Condition	Soil / sediment stability & movement (land context)	Bed load traps and groins (number of structures per 100 km of shoreline)	>100	>50 - 100	>25 - 50	0 - 25	EK	HEC	112	0 (IA)
								WB	211	30.57 (IA)
									212	154.18 (IA)
									213	6.19 (IA)
								CB	311	1.16 (IA)
									312	291.28 (IA)
								EB	411	30.22 (IA)
									413	4.56 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Soil / sediment stability & movement (land context)	Erosion and deposition rates (from tributaries)	High soil erosion by water risk >0.125 t/ac/yr	Moderate soil erosion by water risk 0.075-0.125 t/ac/yr	Low soil erosion by water risk 0.025-0.075 t/ac/yr	Very low soil erosion by water risk <0.025 tons/ac/yr		HEC	112	<6 (NS)
								WB	211	NA
									212	Moderate (NS)
			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)			213	NA
			High soil erosion by water risk >0.125 t/ac/yr	Moderate soil erosion by water risk 0.075-0.125 t/ac/yr	Low soil erosion by water risk 0.025-0.075 t/ac/yr	Very low soil erosion by water risk <0.025 tons/ac/yr		CB	311	High soil (NS)
									312	High soil (NS)
								EB	411	High soil (NS)
									413	NA
Landscape Context	Coastal and watershed contribution	Artificial Shoreline Hardening Index	>40%	>30 - 40%	20 - 30%	<20%		HEC	112	54.63% (NS)
								WB	211	(NS)
									212	35.86% (NS)
									213	46.47% (NS)
								CB	311	17.96% (RA)
									312	38.10% (NS)
								EB	411	25.23% (NS)
									413	40.50% (NS)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Coastal and watershed contribution	Percent natural land cover in watershed	<20	20 - 45	>45 - 80	>80		HEC	112	15.59(NS)
								WB	211	21.96 (NS)
									212	22.06 (NS)
									213	13.85 (NS)
								CB	311	19.25 (NS)
									312	47.48 (NS)
								EB	411	54.42 (NS)
									413	19.67 (NS)
Landscape Context	Coastal and watershed contribution	Percent natural land cover within 2 km of lake	<20	20 - 45	>45 - 80	>80		HEC	112	37.75 (NS)
								WB	211	(NS)
									212	28.73 (NS)
									213	21.26 (NS)
								CB	311	18.95 (NS)
									312	28.83 (NS)
								EB	411	39.29 (NS)
									413	31.69 (NS)
Landscape Context	Landscape pattern (mosaic) & structure	emergent and submergent vegetation distribution in protected embayments 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		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Water chemistry	Dissolved phosphorus load	TBD	TBD	TBD	TBD		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA
Landscape Context	Water chemistry	Nitrogen	TBD	TBD	TBD	TBD		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA
Landscape Context	Water chemistry	Total Phosphorus concentrations (µg/L)	TBD	TBD	TBD	≤20 ug/l	OIR	HEC	112	NA
								WB	211	145 (IA)
									212	145 (IA)
									213	145 (IA)
						≤20 ug/l		CB	311	53 (IA)
									312	53 (IA)
								EB	411	12 (IA)
									413	12 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Water quality	*Cladophora* standing crop (gDW/m2) during late Summer (Aug-Sept)	>80	>30 - 80	15 - 30	<15	ER	HEC	112	NA
								WB	211	(EK)
									212	(EK)
									213	(EK)
								CB	311	(EK)
									312	(EK)
								EB	411	(EK)
									413	(EK)
Landscape Context	Water quality	Contaminants mercury (walleye)	>0.52 ppm	0.52 - 0.39 ppm	0.39 - 0.26 ppm	< 0.26 ppm		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA
Landscape Context	Water quality	Contaminants PCBs (lake trout)	> 0.211 ppm	0.211 - 0.161 ppm	0.161 - 0.105 ppm	< 0.105 ppm		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Water quality	DO concentration	0-2 mg/L	2-4 mg/L	4-6 mg/L	>6mg/L		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA
Landscape Context	Water quality	Extent of harmful algal blooms (e.g., Microcystis, Lyngbya)	TBD	TBD	TBD	TBD		HEC	112	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA
Size	Population size & dynamics	Average Native mussels richness per site	Absent - 2	3 - 10	>10 - 15	>15	EK	HEC	112	NA
			Absent - 2	3 - 5	6 - 15	>15		WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									413	NA

Native Migratory Fish

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Access to Spawning Areas	Percent of Accessible Headwater Stream Habitat (stream order 1)	<25%	25-50%	>50-75%	>75%	EK	HEC	111	41.4 (IA)
									112	58.7 (IA)
									113	66.2 (IA)
								WB	212	23.8 (IA)
									213	80.7 (IA)
								CB	311	54.8 (IA)
									312	41.8 (IA)
								EB	411	31.7 (IA)
									412	52.8 (IA)
									413	13 (IA)
Landscape Context	Access to Spawning Areas	Percent of Accessible Creek Habitat (stream order 2-3)	<25%	25-50%	>50-75%	>75%	EK	HEC	111	40.8 (IA)
									112	56.7 (IA)
									113	67.4 (IA)
								WB	212	26.2 (IA)
									213	79.2 (IA)
								CB	311	52.5 (IA)
									312	40.9 (IA)
								EB	411	31.4 (IA)
									412	42.3 (IA)
									413	11.8 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Access to Spawning Areas	Percent of Accessible Small River Habitat (stream order 4-5)	<25%	25-50%	>50-75%	>75%	EK	HEC	111	59.7 (IA)
									112	51.4 (IA)
									113	56.9 (IA)
								WB	212	20 (IA)
									213	75 (IA)
								CB	311	44.8 (IA)
									312	49.6 (IA)
								EB	411	47.8 (IA)
									412	48.12 (IA)
									413	11.8 (IA)
Landscape Context	Access to Spawning Areas	Percent of Accessible Large River Habitat (stream order >6)	<25%	25-50%	>50-75%	>75%	EK	HEC	112	75.9 (IA)
								WB	212	21.8 (IA)
								CB	311	53.9 (IA)
								EB	412	27.1 (IA)
									413	2.3 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Access to Spawning Areas	Percent of Accessible Tributary Wetland Habitat	<25%	25-50%	>50-75%	>75%	EK	HEC	111	(RG)
									112	(RG)
									113	(RG)
								WB	212	(RG)
									213	(RG)
								CB	311	(RG)
									312	(RG)
								EB	411	(RG)
									412	(RG)
									413	(RG)
Size	Population size & dynamics	Lake sturgeon status across tributaries	<50% of historic rivers with remnant runs and No river with large (1000+ annually) spawning run	>50% of historic rivers with remnant runs or one rivers (depending upon reporting unit) with large (1000+ annually) spawning run	>50% of historic rivers with remnant runs and one river (depending upon reporting unit) with large (1000+ annually) spawning run	>75% of historic rivers with remnant runs and >1 rivers (depending upon reporting unit) with large (1000+ annually) spawning run	ER	HEC	111	(IA)
									112	(IA)
									113	(IA)
								WB	212	0 of 4 (2 remnant) (IA)
									213	2 of 2 (2 remnant) (IA)
								EB	411	1 of 2 (1 remnant) (IA)
									412	1 of1 (1 remnant) (IA)
									413	(EK)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Size	Population size & dynamics	Status of sauger across tributaries	Tributary spawning population <25% of historic (estimated)	Tributary spawning population 25-50% of historic (estimated)	Tributary spawning population 50-75% of historic (estimated)	Tributary spawning population >75% of historic (estimated)	EK	HEC	111	(RG)
									112	(RG)
								WB	212	(RG)
									213	(RG)
Size	Population size & dynamics	status of shorthead redhorse across tributaries	Tributary spawning population <25% of historic (estimated)	Tributary spawning population 25-50% of historic (estimated)	Tributary spawning population 50-75% of historic (estimated)	Tributary spawning population >75% of historic (estimated)	EK	HEC	111	(EK)
									112	(EK)
								WB	212	(EK)
								CB	312	(EK)
								EB	411	(EK)
									413	(RG)
Size	Population size & dynamics	status of walleye across tributaries	Tributary spawning population <25% of historic (estimated)	Tributary spawning population 25-50% of historic (estimated)	Tributary spawning population 50-75% of historic (estimated)	Tributary spawning population >75% of historic (estimated)	EK	HEC	112	(EK)
								WB	213	(EK)
								CB	311	(EK)
									312	(EK)
								EB	411	(EK)
									413	(EK)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Size	Population size & dynamics	Status of white suckers across tributaries	Tributary spawning population <25% of historic (estimated)	Tributary spawning population 25-50% of historic (estimated)	Tributary spawning population 50-75% of historic (estimated)	Tributary spawning population >75% of historic (estimated)	EK	HEC	111	(RG)
									112	(RG)
									113	(RG)
								WB	212	(RG)
									213	(RG)
								CB	311	(RG)
									312	(RG)
								EB	411	(RG)
									412	(RG)
									413	(RG)

Coastal Wetlands

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Abundance and diversity of amphibians	Amphibian community-based coastal wetland Index of Biotic Integrity	0 - 25	>25 - 50	>50 - 75	>75 - 100	OR	HEC	111	NA
									112	20.29 (IA)
									113	29.92 (IA)
								WB	211	33.33 (IA)
									212	15.3 (IA)
									213	47.69 (IA)
								CB	311	37.9 (IA)
									312	58.48 (IA)
								EB	411	37.78 (IA)
									412	55.01 (IA)
									413	34.71 (IA)
Condition	Abundance and diversity of wetland-dependent bird species	Marsh Bird IBI	0 - 20	>20 - 40	>40 - 60	>60		HEC	111	NA
									112	36.27 (NS)
									113	16.16 (NS)
								WB	211	40.48 (NS)
									212	19.85 (NS)
									213	20.64 (NS)
								CB	311	23.94 (NS)
									312	13.11 (NS)
								EB	411	7.15 (NS)
									412	15.15 (NS)
									413	21.52 (NS)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Condition of nested targets	EO ranks of nested natural community targets	<30% A or B ranked	30-50% A or B ranked	>50-70% A or B ranked	>70% A or B ranked	EK	HEC	111	100% (IA)
									112	67 (IA)
									113	100 (IA)
								WB	211	NA
									212	100 (IA)
									213	100 (IA)
								CB	311	100% (IA)
									312	NA
								EB	411	NA
									412	100 % (IA)
									413	52 (IA)
Condition	Condition of nested targets	EO ranks of nested species targets	<30% A or B ranked	30-50% A or B ranked	>50-70% A or B ranked	>70% A or B ranked	EK	HEC	111	50 (IA)
									112	50 (IA)
									113	0 (IA)
								WB	211	50% (IA)
									212	53 (IA)
									213	46 (IA)
								CB	311	36 (IA)
									312	72 (IA)
								EB	411	86 (IA)
									412	50 (IA)
									413	52% (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Fish habitat quality	Wetland Fish Index (WFI) of wetland quality	<2.5	2.5 - 3.25	>3.25 - 3.75	>3.75	OR	HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	1.88 (IA)
									213	NA
								CB	311	3.38 (IA)
									312	3.54 (IA)
								EB	411	NA
									412	3.16 (IA)
									413	3.68 (IA)
Condition	Macro invertebrate quality	Invertebrate IBI	extremely degraded	degraded or moderately degraded	moderately impacted or mildly impacted	reference condition	OR	HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									412	NA
									413	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Plant community integrity	% coverage of phragmites	>50	50 - 20	<20 - 5	<5	EK	HEC	111	NA
									112	NA
									113	37.65 (IA)
								WB	211	50.94 (IA)
									212	21.91 (IA)
									213	NA
								CB	311	NA
									312	44.22 (IA)
								EB	411	NA
									412	NA
									413	NA
Condition	Species composition / dominance	Wetland macrophyte index	<=2	3	4	5	OR	HEC	111	NA
									112	NA
									113	NA
								WB	211	1.88 (IA)
									212	1 (IA)
									213	2.26 (IA)
								CB	311	2.75 (IA)
									312	2.52 (IA)
								EB	411	NA
									412	NA
									413	2.29 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Spawning habitat quality and accessibility	Spawning/recruitment success of representative coastal wetland spawners	Very little recruitment	Some recruitment	Good recruitment	Excellent recruitment		HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
			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		EB	411	NA
									412	NA
									413	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Trophic structure	Wetland Zooplankton Index (WZI)	<1.75	1.75 - 2.75	> 2.75 - 3.75	>3.75	OR	HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	2.32 (IA)
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									412	2.86 (IA)
									413	4.06 (IA)
Landscape Context	Connectivity among communities and ecosystems	Percent natural land cover in watershed	<40	40 - 60	>60 - 80	>80	ER	HEC	111	30.27 (IA)
									112	15.59 (IA)
									113	17.17 (IA)
								WB	211	21.96 (IA)
									212	22.06 (IA)
									213	13.84 (IA)
								CB	311	19.25 (IA)
									312	47.47 (IA)
								EB	411	54.41 (IA)
									412	31.04 (IA)
									413	19.66 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Connectivity among communities and ecosystems	Percent natural land cover within 500 m of mapped wetlands	<20	20 - 40	>40 - 70	>70	EK	HEC	111	73.66
									112	31.36
									113	18.39
								WB	211	
									212	31.84
									213	25.22
								CB	311	30.53
									312	41.98
								EB	411	
									412	33.72
									413	22.76
Landscape Context	Water level regime	Variance in Mar-Oct mean water levels for 30-year rolling period	≤ 0.00095 m	≤ 0.045 m	> 0.045	NA	OR	WB	211	0.058 (IA)
									212	0.058 (IA)
									213	0.058 (IA)
								CB	311	0.058 (IA)
									312	0.058 (IA)
								EB	411	0.058 (IA)
									412	0.058 (IA)
									413	0.058 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Water level regime	Mean growing season (Mar-Oct) water level	≤ 174.1 OR > 176.5 m for 5 consecutive years	≤ 174.1 OR > 176.5 m for any 3 years in a 5-year window	> 174.1 AND ≤ 176.5 m for any 3 years in a 5-year window	NA	OR	HEC	112	>174.1 for 5 consecutive years (IA)
Landscape Context	Water level regime	Mean growing season (Mar-Oct) water level	≤ 173.91 or > 174.59 m for 5 consecutive years	≤ 173.91 or > 174.59 m for any 3 years in a 5-year window	> 173.91 and ≤ 174.59 m for any 3 years in a 5-year window	NA	OR	WB	211	> 173.91 and < 174.59 for 5 consecutive years (IA)
									212	
									213	
								CB	311	
									312	
								EB	411	
									412	
									413	
Landscape Context	Water quality	Mean annual total phosphorous			<30 ug/l			HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									213	NA
									212	NA
								CB	311	NA
									312	NA
								EB	411	NA
									412	NA
									413	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Water quality	Water Quality Index (WQI) for wetland quality	-3 to -1	> -1 to 0	>0 to 1	>1 to 3	OR	HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	-2.42 (IA)
									213	-0.53 (IA)
								CB	311	0.41 (IA)
									312	0.01 (IA)
								EB	411	NA
									412	NA
									413	0.32 (IA)
Size	Size / extent of characteristic communities / ecosystems	Wetland area	greater loss from current area	some loss from current area	current area	historic area	RG	HEC	111	986 acres (IA)
									112	33,417 acres (IA)
			<= 4,215 acres	> 4,215 and < 8,430 acres	≥ 8,430 and < 16,860 acres	≥ 16,860 acres			113	4,215 acres (IA)
			greater loss from current area	some loss from current area	current area	historic area		WB	211	2 acres (IA)
									212	19,325 acres (IA)
									213	5,931 acres (IA)
								CB	311	3,000 acres (IA)
									312	577 acres (IA)
								EB	411	0 acres (IA)
									412	1,336 acres (IA)
									413	42,78 acres (IA)

Connecting Channels

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Channel condition	Shoreline hardening	>40%	30 - 40%	20 - 30%	<20%		HEC	111	71.6% (IA)
									112	54.63% (IA)
									113	66.13% (IA)
								EB	412	77.09% (IA)
Condition	Community architecture	Fish species richness - spawning	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		HEC	111	NA
									112	NA
									113	NA
								EB	412	NA
Condition	Community architecture	Fish species richness- larval	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		HEC	111	NA
									112	NA
									113	NA
								EB	412	NA
Condition	Community architecture	Wetland area	greater loss from current area	some loss from current area	current area	historic area		HEC	111	986 acres (IA)
									112	33,417 acres (IA)
			some loss from current area	Current area	10% increase over 2012 area	historic area			113	4,215 acres (IA)
			greater loss from current status	some percentage loss from current status	current area	historic area		EB	412	13336 acres (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Fish tissue	Contaminant load	TBD	TBD	TBD	TBD		HEC	111	NA
									112	NA
									113	NA
								EB	412	NA
Condition	Population structure	5-year average of annual peak density of whitefish larvae	<10/1000 m^3	10-25/1000 m^3	>25-100/1000 m^3	>100/1000 m^3		HEC	111	0 (IA)
									113	(IA)
Landscape Context	Water quality	DO concentration			>5 mg/L	Saturated		HEC	111	Saturated (NS)
									112	Saturated (NS)
									113	Saturated (NS)
								EB	412	NA
Landscape Context	Water quality	Hexagenia densities (no./m^2)	<2	2-19	20-200	>200		HEC	111	(NS)
									112	(NS)
									113	(NS)
								EB	412	NA
Landscape Context	Water quality	Mean Mar-Oct Water levels (m)	Maintained at or below 174.3 OR above 176.5 for 5 consecutive years	Maintained at or below 174.3 OR above 176.5 for any 3 years in a 5 year window	Maintained between 174.3 and 176.5 for at least 3 out of 5 years running	Maintained between 174.3 and 176.5 for 5 years running		HEC	112	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Water quality	TDS	TBD	TBD	TBD	TBD		HEC	111	NA
									112	NA
									113	NA
								EB	412	NA
Landscape Context	Water quality	Total Phosphorus concentrations (µg/L)	TBD	TBD	TBD	TBD		HEC	111	NA
									112	NA
									113	NA
								EB	412	NA
Size	Population size & dynamics	Average native mussels richness per site	Absent - 2 spp	3 - 10 spp	>10 - 15 spp	>15 spp	EK	HEC	111	NA
									112	NA
									113	NA
								EB	412	12 (NS)
Size	Population size & dynamics	Mean Dreissena density	Abundant			Absent		HEC	111	NA
									112	NA
									113	NA
								EB	412	NA
Size	Population size & dynamics	Native mussel abundance	TBD	TBD	TBD	TBD		HEC	111	NA
									112	NA
									113	NA
								EB	412	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Size	Population size & dynamics	Number mature lake sturgeon	no breeding individuals	>50 breeding individuals or at least 5% of population	>100 breeding individuals or at least 10% of population	>500 breeding individuals or at least 15% of population		HEC	111	16,000 (IA)
								HEC	112	16,000 (IA)
								HEC	113	5,000 (IA)
								EB	412	NA

Islands

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Condition of nested targets	EO ranks of nested natural community targets	<30% A or B ranked	30-50% A or B ranked	>50-70% A or B ranked	>70% A or B ranked	RG	HEC	111	NA
									112	64 (IA)
									113	100 (IA)
								WB	211	100 (IA)
									212	100 (IA)
								CB	311	0 (IA)
									312	0 (IA)
								EB	411	NA
									412	100 (IA)
									413	NA
Condition	Condition of nested targets	EO ranks of nested species targets	<30% A or B ranked	30-50% A or B ranked	>50-70% A or B ranked	>70% A or B ranked	RG	HEC	111	NA
									112	43 (IA)
									113	67 (IA)
								WB	211	53 (IA)
									212	47 (IA)
								CB	311	NA
									312	100 (IA)
								EB	411	0 (IA)
									412	53 (IA)
									413	100 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Connectivity among communities & ecosystems	Road density (m road / km^2)	<2,000	>1,250 - 2,000	500 - 1,250	<500	EK	HEC	111	272.95 (IA)
									112	1052.43 (IA)
									113	4370.32 (IA)
								WB	211	1052.43 (IA)
									212	4164.26 (IA)
								CB	311	0 (IA)
									312	1630.09 (IA)
								EB	411	0 (IA)
									412	3251 (IA)
									413	16.90 (IA)
Condition	Landscape pattern (mosaic) & structure	House density on island (number of buildings/ km^2)	>40	21 - 40	11 - 20	<10	EK	HEC	111	174.19 (IA)
									112	10.95 (IA)
									113	145.59 (IA)
								WB	211	36.99 (IA)
									212	90.25 (IA)
								CB	311	0.64 (IA)
									312	0 (IA)
								EB	411	0 (IA)
									412	101.12 (IA)
									413	1.49 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Size / extent of characteristic communities / ecosystems	Percent natural land cover on entire island	<20	20 - 40	>40 - 70	>70	ER	HEC	111	45.96 (IA)
									112	67.95 (IA)
									113	37.63 (IA)
								WB	211	33.36 (IA)
									212	42.07 (IA)
								CB	311	94.67 (IA)
									312	76.01 (IA)
								EB	411	0 (IA)
									412	62.21 (IA)
									413	95.28 (IA)
Condition	Soil / sediment stability & movement	Artificial Shoreline Hardening Index	>40	>20 - 40	10 - 20	<10	EK	HEC	111	85 (IA)
									112	15.84 (IA)
									113	53.75 (IA)
								WB	211	25.68 (IA)
									212	23.61 (IA)
								CB	311	10.13 (IA)
									312	25.92 (IA)
								EB	411	0 (IA)
									412	39.75 (IA)
									413	7.97 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Soil / sediment stability & movement	Bed load traps and groins (number of structures per 100 km of shoreline)	>100	>50 - 100	>25 - 50	0 - 25	EK	HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	NA
								CB	311	NA
									312	NA
								EB	411	NA
									412	NA
									413	NA
Landscape Context	Conservation status	Percentage of high-ranked islands that are in conservation status	<20	20 - 40	>40 - 70	>70	ER	HEC	111	0 (IA)
									112	28.5 (IA)
									113	0 (IA)
								WB	211	29.72 (IA)
									212	0 (IA)
									213	0 (IA)
								CB	311	37.98 (IA)
									312	0 (IA)
								EB	411	0 (IA)
									412	2.78 (IA)
									413	41.2 (IA)

Coastal Terrestrial Systems

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Condition of nested targets	EO ranks of nested natural community targets	<25% A or B ranked	25-50% A or B ranked	>50-75% A or B ranked	>75% A or B ranked	EK	HEC	111	0% (IA)
									112	0% (IA)
									113	33 (IA)
								WB	211	0% (IA)
									212	72 (IA)
									213	75 (IA)
								CB	311	27 (IA)
									312	62 (IA)
								EB	411	75 (IA)
									412	40 (IA)
									413	50 (IA)
Condition	Condition of nested targets	EO ranks of nested species targets	<25% A or B ranked	25-50% A or B ranked	>50-75% A or B ranked	>75% A or B ranked	EK	HEC	111	29% (IA)
									112	56 (IA)
									113	41% (IA)
								WB	211	50 (IA)
									212	43% (IA)
									213	45% (IA)
								CB	311	37 (IA)
									312	70 (IA)
								EB	411	38 (IA)
									412	30 (IA)
									413	50 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Connectivity among communities & ecosystems	Road density (m road / km^2)	>2,000	1,250 - 2,000	500 - 1,250	<500	EK	HEC	111	4557.55 (IA)
									112	3334.28 (IA)
									113	7731.26 (IA)
								WB	211	NA
									212	4975.66 (IA)
									213	2513.35 (IA)
								CB	311	1276.30 (IA)
									312	7539.32 (IA)
								EB	411	5533.49 (IA)
									412	5913.46 (IA)
									413	1846.65 (IA)
Condition	Landscape pattern (mosaic) & structure	House density within 500 m of coast (number of buildings/ km^2)	>40	21 - 40	11 - 20	<10	EK	HEC	111	260.50 (IA)
									112	132.45 (IA)
									113	290.06 (IA)
								WB	211	NA
									212	162.29 (IA)
									213	132.75 (IA)
								CB	311	28.98 (IA)
									312	379.45 (IA)
								EB	411	152.23 (IA)
									412	260.20 (IA)
									413	64.49 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Size / extent of characteristic communities / ecosystems	Percent natural land cover within 2 km of shoreline	<20	20 - 40	>40 - 70	>70	ER	HEC	111	24.39 (IA)
									112	37.75 (IA)
									113	15.19 (IA)
								WB	211	NA
									212	28.73 (IA)
									213	21.26 (IA)
								CB	311	18.95 (IA)
									312	28.83 (IA)
								EB	411	39.29 (IA)
									412	34.29 (IA)
									413	31.69 (IA)
Condition	Soil / sediment stability & movement	Artificial Shoreline Hardening Index	>40%	>20 - 40%	10 - 20%	<10%	EK	HEC	111	71.6 (IA)
									112	54.63 (NS)
									113	66.13 (IA)
								WB	211	NA
									212	35.86 (IA)
									213	46.47 (IA)
								CB	311	17.96 (IA)
									312	38.10 (IA)
								EB	411	25.23 (IA)
									412	77.09 (IA)
									413	40.50 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Condition	Soil / sediment stability & movement	Bed load traps and groins (number of structures per 100 km of shoreline)	>100	>50 - 100	>25 - 50	0 – 25	EK	HEC	111	9.29 (IA)
									112	0 (NS)
									113	2.35 (IA)
								WB	211	30.57 (IA)
									212	154.18 (IA)
									213	6.19 (IA)
								CB	311	1.16 (IA)
									312	291.28 (IA)
								EB	411	30.22 (IA)
									412	1.99 (IA)
									413	4.56 (IA)
Landscape Context	Coastal land use	Percentage of area 2-10 km from lake that is in natural land cover	<20%	20 - 40%	>40 - 70%	>70%	ER	HEC	111	25.2 (IA)
									112	11.37 (IA)
									113	7.96 (IA)
								WB	211	NA
									212	17.98 (IA)
									213	7.41 (IA)
								CB	311	15.39 (IA)
									312	38.88 (IA)
								EB	411	49.32 (IA)
									412	19.17 (IA)
									413	23.98 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Soil / sediment stability & movement in contributing area	Artificial Shoreline Hardening Index in contributing area	>40%	>20 - 40%	10 - 20%	<10%	EK	HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									412	NA
									413	NA
Landscape Context	Soil / sediment stability & movement in contributing area	Bed load traps and groins (number of structures per 100 km of shoreline in contributing areas)	>100	>50 - 100	>25 - 50	0 - 25	EK	HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									412	NA
									413	NA

Aerial Migrants

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Anthropogenic disturbance	Average distance of suitable shorebird habitat from disturbance factor (m)	<100	100 - <200	>200	>250	ER	HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									412	NA
									413	NA
Landscape Context	Anthropogenic disturbance	Average distance of suitable waterfowl habitat from disturbance factor (m)	<100	100 - <200	>200	>250	ER	HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									412	NA
									413	NA

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Habitat availability	Percentage of 2 km shoreline area that is suitable for shorebirds	<10	10 - 30	>30 - 50	>50	OR	HEC	111	25 (IA)
									112	55 (IA)
									113	13 (IA)
								WB	211	50 (IA)
									212	40 (IA)
									213	82 (IA)
								CB	311	71 (IA)
									312	2 (IA)
								EB	411	14 (IA)
									412	4 (IA)
									413	50 (IA)
Landscape Context	Habitat availability	Percentage of 2 km shoreline area that is suitable habitat for landbirds	<10	10 - 30	>30 - 50	>50	OR	HEC	111	42 (IA)
									112	45 (IA)
									113	36 (IA)
								WB	211	35 (IA)
									212	44 (IA)
									213	17 (IA)
								CB	311	16 (IA)
									312	60 (IA)
								EB	411	63 (IA)
									412	62 (IA)
									413	39 (IA)

KEA Type	KEA	Indicator	Poor	Fair	Good	Very Good	RS	RU	AU	Current Value (Source)
Landscape Context	Habitat availability	Percentage of 2 km shoreline area that is suitable habitat for waterfowl	<30	30 - 50	>50 - 80	>80	OR	HEC	111	46 (IA)
									112	75 (NS)
									113	39 (IA)
								WB	211	94 (IA)
									212	72 (IA)
									213	92 (IA)
								CB	311	82 (IA)
									312	28 (IA)
								EB	411	33 (IA)
									412	29 (IA)
									413	61 (IA)
Landscape Context	Management Status	Percentage of high priority habitat across all bird groups, that is in conservation management	<50	50 - 80	>80 and <100	100	OR	HEC	111	NA
									112	NA
									113	NA
								WB	211	NA
									212	NA
									213	NA
								CB	311	NA
									312	NA
								EB	411	NA
									412	NA
									413	NA

APPENDIX F: INDICATOR DESCRIPTIONS

3-year running average total native intolerant fish species richness in annual bottom trawl surveys

KEA (Type): Community architecture (Condition)

Target: Nearshore Zone

Description: The regularly collected trawl data from Great Lakes Fishery Commission member agencies can be analyzed for species richness, and trends can be analyzed to assess levels of eutrophication. A running average would recognize variability from inter-annual fluctuations. The following ratings are suggested by the authors based on a review of Ludsin et al. (2011):

	Poor	Fair	Good	Very Good
Western Basin	<2	2- 3	>3-4	>4
Central Basin	≤2	2-3	>3-4	≥5

Basis for Assessing Indicator: The survival or presence of many intolerant fish species depends on response to differing levels of eutrophication, which results in stressful conditions such as low oxygen and turbidity. Nutrient-driven reductions in tolerant species also can cause species richness to decline (Ludsin et al. 2001).

5-year average of annual peak density of whitefish larvae

KEA (Type): Population structure (Condition)

Target: Connecting Channels

Description: This indicator reflects the recently discovered presence of spawning whitefish and ongoing survey efforts in the Huron – Erie Corridor (Roseman et al. 2007). The presence of spawning whitefish is an indicator of steadily improving water quality since the adoption of the GLWQA in 1972, and can serve as a positive and motivational symbol of system recovery (Ed Roseman, USGS Great Lakes Science Center, pers. comm.).

Basis for Assessing Indicator: Ratings and current status values for this indicator are based on ongoing surveys (Roseman et al. 2012) and expert opinion (Ed Roseman, USGS Great Lakes Science Center, pers. comm.), and may only apply well to the Detroit River. We recommend evaluation of this indicator with respect to the St. Clair and Upper Niagara Rivers as a need for further research.

5-year trend in burbot biomass

KEA (Type): Predator fish species population size (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Burbot is a top predator in the offshore and is an indicator of ecosystem health as well.

Basis for Assessing Indicator: Data are compiled by the Lake Erie Coldwater Task Group of the GLFC.

5-year trend in lake whitefish abundance

KEA (Type): Population size & dynamics (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Lake whitefish are an important component of the offshore food web, representing the only still viable coregonid population of Lake Erie. These fish are still important commercially in Ontario.

Basis for Assessing Indicator: The rating is based on call with OMNR fisheries managers. While fishers are catching reasonable numbers, lake whitefish appear to be in decline due to recruitment. Documenting the trend requires a minimum of five years of data. It is hard to set levels because what is *Good* depends on what lake could support. Conditions vary over time and what used to be good is not necessarily the same now.

Alewife density

KEA (Type): Mid-level prey abundance (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator was included because managers in Lake Erie do not want to have a reliance on alewife as a food source because their abundance is very unstable. Alewife can also have a significant impact (negative) on the plankton community as juveniles.

Basis for Assessing Indicator: The scale was suggested by Kevin Kayle. The data are compiled by the Lake Erie Lake Committee Forage Task group

Amphibian community-based coastal wetland Index of Biotic Integrity

KEA (Type): Abundance and diversity of amphibians (Condition)

Target: Coastal Wetlands

Description: This indicator captures the status of amphibians—specifically frogs and toads (anurans) in Coastal Wetlands. It is essentially the same as SOLEC draft indicator for Wetland Anurans (Tozer 2011), and is part of a Great Lakes basin-wide monitoring project funded through theU.S. EPA Great Lakes Restoration Initiative. It builds upon previous work of the Great Lakes Coastal Wetland Consortium and Great Lakes Environmental Indicators projects (Matthew Cooper, Notre Dame University, pers. comm.).

Basis for Assessing Indicator: We obtained data from Bird Studies Canada, who has coordinated surveys on over 200 marsh routes in Lake Erie for up to 15 years through the volunteer based Marsh Monitoring Program (Archer and Jones 2009). Using ArcMap, we calculated the average of the amphibian IBI values for all marsh routes in each assessment unit.

Artificial Shoreline Hardening Index

KEA (Type): Coastal and watershed contribution (Landscape Context)

Target: Nearshore Zone

KEA (Type): Soil / sediment stability & movement (Condition)

Target: Coastal Terrestrial Systems and Islands

KEA (Type): Channel Condition

Target: Connecting Channels

Description: This indicator reflects the 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, Mackey 2008, Morang et al. 2011, Morang et al. 2012). In Connecting Channels, hardened shorelines have destroyed wetlands and wildlife habitat and alter the flow regime of these rivers by preventing high waters from flooding inland, redirecting energy downstream. Despite knowledge that the impacts of shoreline hardening have been profound, the impacts of shoreline hardening have been understudied in the Great Lakes (Mackey and Liebenthall 2005) and have received little attention in efforts to protect or restore coastal systems.

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. GIS analysis were conducted in ArcMap to calculate the shoreline harding index for each assessment unit.

Artificial Shoreline Hardening Index in contributing area

KEA (Type): Soil / sediment stability & movement in contributing area (Landscape Context)

Target: Coastal Terrestrial Systems

Description: The rationale for this indicator is very similar to the one directly above, and recognizes the important role that long shore currents play in sediment transport and shoreline dynamics. Hardened shorelines substantially alter processes of erosion and accretion of sediments and the configuration of the shoreline not only where the shoreline is altered but “downstream” of the hardened areas.

Basis for Assessing Indicator: Due to insufficient understanding of the processes of sediment transport and deposition for Lake Michigan, we were not able to designate contributing areas for the assessment units in Lake Michigan, so we were not able to assess the current status of this indicator. We recommend further refinement of this indicator for future status assessments.

Average distance of suitable shorebird habitat from disturbance factor (m)

KEA (Type): Anthropogenic disturbance (Landscape Context)

Target: Aerial Migrants

Description: This indicator is based on response of shorebirds to anthropogenic disturbance factors such as hiking, response to dogs accompanied by people

Basis for Assessing Indicator: Threshold values were derived from Borgmann (2011) and references therein.

Average distance of suitable waterfowl habitat from disturbance factor (m)

KEA (Type): Anthropogenic disturbance (Landscape Context)

Target: Aerial Migrants

Description: This indicator is based on response of waterfowl to anthropogenic disturbance factors such as hiking, response to dogs accompanied by people as well as response to boats.

Basis for Assessing Indicator: Threshold values were derived from Borgmann (2011) and references therein

Average Native mussel richness per site

KEA (Type): Population size & dynamics (Size)

Target: Connecting Channels and Nearshore

Description: This indicator is based on the number of species collected at each site through freshwater mussel (Unionidae) surveys along the range of nearshore habitats in Lake Erie, and for the Huron-Erie Corridor. Experts stated there is not enough information to suggest rankings for the Upper Niagara River. Freshwater mussels are of significant interest in North American given the high diversity of this taxa in North America and the high level imperilment of this group (Master 1990), as well as the ecological functions they provide (Vaughn et al. 2008). Among these ecological functions is their ability to filter large volumes of water, which helps to temper algal populations in productive areas and helps to reduce turbidity. Historically much more abundant and rich in diversity, Lake Erie's native mussels have experienced a major decline over the decades, most likely due to water quality (Nalepa et al. 1991) and the dreissenid invasion (zebra and quagga) mussels (Schloesser et al. 2006).

Basis for Assessing Indicator: Recent (2009-2011) U.S. data is available (Pers. Comm., David Zanatta, Central Michigan University, 2011; Lyubov Burlakova, Buffalo State College, 2011; Crail, T.D., R.A. Krebs, and D.T. Zanatta. 2011. Based on a recent survey led by Zanatta and on expert opinion, the following ratings are recommended for the nearshore and the Huron-Erie Corridor, and also tentatively for the Upper Niagara River, though that system was not historically as rich in mussel species as the others (Pers. Comm., Lyuba Burlakova, Buffalo State College, 2011):

Poor: Absent - 2 spp.; *Fair*: Species richness 3-5 spp; *Good*: Species richness 6-15 spp; *Very Good*: Species richness > 15 spp.

Only very limited recent quantitative data on molluscs of the Niagara River is known (Pers. comm., Lyuba Burlakova, Buffalo State College, 2011). The number of species is likely to be lower than the Huron-Erie Corridor or Nearshore Zone.

Bed load traps and groins (number of structures per 100 km of shoreline)

KEA (Type): Soil / sediment stability & movement (Condition)

Target: Nearshore Zone, Coastal Terrestrial Systems and Islands

Description: This indicator measures the number of artificial shoreline 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 or docks, so further evaluation of this indicator ratings is needed in the future.

Basis for Assessing Indicator: Published studies are generally insufficient for identifying thresholds of impacts from perpendicular structures in the lake. Due to the paucity of research, the Core Team determined the thresholds based on expert opinion. As additional research is completed on the impacts of bed load traps and groins, we anticipate that these thresholds will be revised.

Bed load traps and groins (number of structures per 100 km of shoreline in contributing areas)

KEA (Type): Soil / sediment stability & movement in contributing area (Landscape Context)

Target: Coastal Terrestrial Systems

Description: See the indicator directly above for the description of this indicator. We recognize that long shore currents transport sediments around the lake, and that shoreline structures can alter those patterns of erosion, transport, and deposition. This indicator should be developed and incorporated into the viability assessment to better capture the effects of this disruption on sediment transport processes.

Basis for Assessing Indicator: Due to insufficient understanding of the processes of sediment transport and deposition for Lake Michigan, we were not able to designate contributing areas for the assessment units in Lake Michigan, so we were not able to assess the current status of this indicator. We recommend further refinement of this indicator for future status assessments.

Benthic Diversity and Abundance

KEA (Type): water quality (Landscape Context)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator is based on the oligochaete trophic condition index (Milbrink 1983) and is a SOLEC indicator for Lake Erie. We wanted to represent the benthos and this indicator was supported by Ken Krieger, Heidelberg University (pers. comm.).

Basis for Assessing Indicator: See SOLEC indicator #104 (SOLEC 2011).

Cladophora standing crop (gDW/m2) during late Summer (Aug-Sept)

KEA (Type): Water quality (Landscape Context)

Target: Nearshore Zone

Description: *Cladophora* is a nuisance alga that grows on rocks and other structures at the bottom of lakes and other water-bodies. The Eastern Basin of Lake Erie has experienced the most excessive growth in recent years and has received considerable attention from lake users. The substantial physical and chemical changes in habitat conditions cause by *Cladophora* can substantially alter native species populations (Ward and Ricciardi 2010).

Basis for Assessing Indicator: Ratings are based on relationships in Auer et al. (2010) and input from Bootsma (pers. comm.). Current status of *Cladophora* standing crop is based on D. Kane, Defiance College (pers. comm. 2011).

Contaminant load

KEA (Type): Fish tissue (Condition)

Target: Connecting Channels

Description: This indicator was recommended by experts, but was never fully defined. The following two indicators, developed for the Nearshore Zone, could be applied to Connecting Channels as well. There are also a few indicators that are being monitored in the Connecting Channels, including mercury in walleyes in Lake St. Clair (Hayton 2007), and contaminants in Western Lake Erie fish community (Backus 2007). In the Niagara River, recent studies of contaminants in the sport fish community (Karst-Riddoch et al. 2008) should be evaluated and potentially adopted as an indicator for that connecting channel.

Basis for Assessing Indicator: We did not make a final decision on this indicator for the Connecting Channels.

Contaminants mercury (walleye)

KEA (Type): Water quality (Landscape Context)

Target: Nearshore Zone

Description: This indicator has been tracked by over 25 years by either the U.S. EPA or Environment Canada, primarily in recognition of the human health implications of eating fish with high concentrations of Mercury (McGoldrick et al. 2011).

Basis for Assessing Indicator: The target established for human health reasons of 0.5 µg/g ww, is still being met, though mercury levels are on the rise and have returned to levels observed in the 1980s (McGoldrick et al. 2011).

Contaminants PCBs (walleye)

KEA (Type): Water quality (Landscape Context)

Target: Nearshore Zone

Description: As with the above indicators, this one has been established primarily for human health concerns. It can serve well as an indicator of water quality, along with measures of other contaminants. For a complete description, see McGoldrick et al. (2011).

Basis for Assessing Indicator: As described in McGoldrick et al. (2011), PCBs have been declining since the 1970’s but are still above the target of 0.1 µg/g ww, as established by the Great Lakes Water Quality Agreement.

Coregonids: lake whitefish – Growth based on length to width ratio

KEA (Type): Population structure & recruitment (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator has not been rated yet due to insufficient data. The OMNR fisheries managers interviewed suggested that length to width ration is a good measure of growth and would be good to include.

Basis for Assessing Indicator: not assessed

Coregonids: lake whitefish – number of year classes > yr 5 that are well represented (down grade if uneven distribution)

KEA (Type): Population structure & recruitment (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Currently lake whitefish populations are dominated by 2-3 year classes (there are only three that represent more than 10% of the population). The greater number of mature year classes well represented would suggest greater stability in whitefish populations into the future

Basis for Assessing Indicator: Based on data compiled and presented by the Coldwater Task Group of the Lake Erie Lake Committee.

Dissolved Oxygen - mean hypolimnetic DO when water column is stratified - frequency distribution of known data

KEA (Type): Water quality (Landscape Context)

Target: Open Water Benthic and Pelagic Ecosystem

Description: A dissolved oxygen level of less than 4 mg/l is stressful to fish. For the Central Basin – which is mesotrophic and supports a cool water fish community, we used a rating of 4 mg/l as the critical threshold. For the open waters of the Eastern Basin, we adopted 6 mg/l, a more stringent threshold, as that habitat supports a coldwater community (EPA 1988). Because the Central Basin of Lake Erie does have a hypoxic zone - we thought this was an important indicator of water quality. Ideally we would have a measure of the temporal duration and spatial extent of DO over a five year period and also recognize that macroinvertebrates may be more tolerant of lower levels - so the rating scale could be adjusted downward for them.

Basis for Assessing Indicator: The data come from the Forage Task Group of the Lake Erie Lake Committee (GLFC).

Dissolved phosphorus loads

KEA (Type): Water chemistry (Landscape Context)

Target: Nearshore Zone

Description: To reduce Harmful Algal Blooms and nuisance algae, and generally restore the Lake Erie ecosystem to an acceptable level, measurement and reduction of phosphorus loads to Lake Erie are necessary.

Basis for Assessing Indicator: Heidelberg University monitoring program data (e.g., see Richards et al. 2007) supplemented by point source and other estimates.

DO concentration

KEA (Type): Water quality (Landscape Context)

Target: Nearshore Zone and Connecting Channels

Description: Krieger and Bur (2009) defined hypoxia as a dissolved oxygen concentration of less than 2.0 mg/L, and the Great Lakes Fishery Commission states "Dissolved oxygen less than 4 mg/L is deemed stressful to fish and other aquatic biota" (GFLC 2011, pg. 39).

Basis for Assessing Indicator: http://www.glerl.noaa.gov/ifyle/ A primary objective of the NOAA International Field Years on Lake Erie (IFYLE) program is to "quantify the spatial extent of hypoxia across the lake, and gather information that can help forecast its timing, duration, and extent." "The EPA Great Lakes National Program Office (GLNPO) monitors the status of dissolved oxygen in the water column of Lake Erie at a fixed network of stations several times each summer." http://www.epa.gov/grtlakes/monitoring/d_o/index.html.

Emergent and submergent vegetation distribution in protected embayments and soft sediment areas

KEA (Type): Landscape pattern (mosaic) & structure (Landscape Context)

Target: Nearshore Zone

Description: Although not covered further in this document, to support phytophilic fish, another indicator could include the areal extent of submerged aquatic macrophytes. This vegetation is affected by pollutants (Hartig et al. 2007) and exotic species (Knapton and Petrie 1999). These are important to fish in the nearshore lake margin (e.g., Glass et al. 2012), and the Great Lakes Fishery Commission (2012, p. 29) includes a goal of "*Restore submerged aquatic macrophyte communities in estuaries, embayments, and protected nearshore areas*"

Basis for Assessing Indicator: We did not find sufficient data to evaluate this indicator, though some researchers have mapped submerged aquatic vegetation in the Detroit River. See the Detroit River – Western Lake Erie Indicators Project "Recovery of Wildcelery" indicator for references to multiple studies conducted in the Detroit River (Schloesser et al. 2009).

Element Occurrence (EO) ranks of selected nested features (includes community and species targets)

KEA (Type): Condition of nested targets (Condition)

Target: Coastal Terrestrial Systems, Coastal Wetlands and Islands

Description: This indicator measures the percentage of A-B element occurrence ranks of all A-D ranked element occurrences. Element occurrence ranks (provincial/state) are used to assess the viability of individual species and natural community occurrences found along the Lake Michigan coastal zone (see the list of nested features in the introduction of the Coastal Terrestrial Systems section). These ranks are provided by the heritage programs from each state: Wisconsin Natural Heritage Inventory, Illinois Department of Natural Resources, Division of Natural Heritage, Indiana Department of Natural Resources, Division of Nature Preserves, and the Michigan Natural Features Inventory (MNFI).

Basis for Assessing Indicator: Thresholds for this indicator were based on expert opinion. Issues associated with this indicator include: lack of systematic surveys, older records, and inconsistencies in tracking and evaluating element occurrences between states and provinces.

Erosion and deposition rates (from tributaries)

KEA (Type): Soil / sediment stability & movement (land context) (Condition)

Target: Nearshore Zone

Description: This indicator reflects the rates of erosion and deposition from Lake Erie tributaries. Erosion from tributaries is the largest contributor of sediment to Lake Erie, and is tightly linked to phosphorus. Eroded sediments have both direct and indirect impacts to the ecology of Lake Erie (Richards et al. 2008). Erosion rates have been measured and modeled, especially in the Maumee River watershed, the largest in Lake Erie and the greatest single contributor of sediment and phosphorus.

Basis for Assessing Indicator: Ratings for this indicator are based on 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).

Extent of harmful algal blooms (e.g., *Microcystis*, *Lyngbya*)

KEA (Type): Water quality (Landscape Context)

Target: Nearshore Zone

Description: This indicator would measure how far algal blooms extend across the lake. In the recent past, this has included much of the Western Basin and into a smaller part of the Central Basin. The most outstanding issue for the Lake Erie nearshore is that of nutrient pollution and eutrophication, and resultant Harmful Algal Blooms (HABs). Loadings of phosphorus are correlated with the extent of blooms. This measure would determine the areal extent of HABs such as measured by NOAA satellite tracking.

Basis for Assessing Indicator: While data collection is well underway, this indicator has not been rated yet due to insufficient data and the need for expert determinations of objectives and ratings. The state of knowledge on what objectives should be set needs more development. These measures should be recognized with “placeholders:”

- Extent of HABs as measured by NOAA satellite data (NOAA 2012a)
- Concentration of HABs in lake water (such as through measurements by the University of Toledo) (Chaffin et al. 2011; Bridgeman et al. 2012)

- Frequency of HAB advisories (such as measured by State of Ohio beach water monitoring) (http://ohioalgaeinfo.com/)
- HAB toxin concentrations in intakes at public drinking water treatment plants (Trinka Mount, Ohio EPA, pers. comm. 2012)

Fish species richness – larval

KEA (Type): Community architecture (Condition)

Target: Connecting Channels

Description: There is evidence of increasing spawning activity by species, such as lake whitefish, that historically spawned in large numbers in the Detroit River but that have been absent or very rare for many decades (Roseman et al., 2007). As such, tracking the richness of larval species can be an effective indicator of the recovery of the Detroit River (Pers. comm., Ed Roseman, USGS Great Lakes Science Center, October 2011).

Basis for Assessing Indicator: The ratings for this indicator are expressed in relative terms; further research is necessary to enable quantitative assessment of this indicator. Larval fish surveys are being conducted following Roseman et al. (2007).

Fish species richness – spawning

KEA (Type): Community architecture (Condition)

Target: Connecting Channels

Description: As with the above indicator, there is evidence of increasing spawning activity by species, such as lake whitefish, that historically spawned in large numbers in the Detroit River but that have been absent or very rare for many decades (Roseman et al., 2007). Other species including lake sturgeon, walleye, and muskellunge are known to spawn in the Detroit, St. Clair, and Upper Niagara Rivers and Lake St. Clair (Manny et al., 2010; Kapuscinski et al., 2010; Thomas and Haas, 2004). As such, tracking the richness of spawning species can be an effective indicator of the recovery of these connecting channels (Pers. comm., Ed Roseman, USGS Great Lakes Science Center, October 2011).

Basis for Assessing Indicator: The ratings for this indicator are expressed in relative terms; further research is necessary to enable quantitative assessment of this indicator.

Hexagenia densities (no./m2)

KEA (Type): Water quality (Landscape Context)

Target: Connecting Channels

Description: *Hexagenia* are important indicators of nearshore health in more productive areas of the Great Lakes that are dominated by soft substrates (Edsall et al. 2005). In addition, Hexagenia can be a very important food source to many benthic feeding fishes, including lake sturgeon (Beamish et al. 1998, Choudhury et al. 1996), yellow perch (Price 1963, Clady and Hutchinson 1976), and walleye (Ritchie and Colby 1988).

Basis for Assessing Indicator: Indicator ratings and current status are based on Edsall et al. (2005) and EC and EPA (2009, p. 127).

Hexagenia mean density in fine sediments (3 yr average)

KEA (Type): Food web linkages (Condition)

Target: Nearshore Zone and Open Water Benthic and Pelagic Ecosystem

Description: *Hexagenia*, a dominant benthic organism in the Nearshore Zone, are important indicators of nearshore health in more productive areas of the Great Lakes that are dominated by soft substrates (Edsall et al. 2005). In addition, Hexagenia can be a very important food source to many benthic feeding fishes, including lake sturgeon (Beamish et al. 1998, Choudhury et al. 1996), yellow perch (Price 1963, Clady and Hutchinson 1976), and walleye (Ritchie and Colby 1988). "Hexagenia can be a useful indicator of lake quality where its distribution and abundance are limited by anthropogenic causes" (Krieger et al. 2007, p. 20), and the status of the Western and Central Basins have been a focus of study (Krieger 2004).

Basis for Assessing Indicator: Indicator ratings and current status are based on expert opinion from K. Krieger, Heidelberg University (pers. comm. 2012), Krieger (2004) and Krieger et al. (2007).

House density on island (number of buildings/km^2)

KEA (Type): Landscape pattern (mosaic) & structure (Condition)

Target: Islands

Description: This indicator describes the density of houses on islands in Lake Erie. Housing density is a reasonable estimator of the degree of fragmentation and disturbance. The ratings for this indicator need to be further evaluated as we could not find applicable literature that provided evidence for the relationship between house density and ecosystem viability, and experts were not highly confident of the ratings.

Basis for Assessing Indicator: For U.S. islands, we used census block data (U.S. Census Bureau 2000) to provide an estimate of housing density for each island. For Ontario islands, we used the Ontario building layer from the Ontario Ministry of Natural Resources (2006). For each island, we used ArcMap to determine the number of houses on each island, and then divided the number of houses by total area of each island in km^2.

House density within 500 m of coast (number of buildings/ km^2)

KEA (Type): Landscape pattern (mosaic) & structure (Condition)

Target: Coastal Terrestrial Systems

Description: This indicator describes the density of houses within 500 m of the Lake Erie shoreline. Housing density is a reasonable estimator of the degree of fragmentation and disturbance within a coastal assessment unit. The ratings for this indicator need to be further evaluated as we could not find applicable literature that provided evidence for the relationship between house density and ecosystem viability, and experts were not highly confident of the ratings.

Basis for Assessing Indicator: For the U.S. coastal area, we used census block data (U.S. Census Bureau 2000) and for Ontario, we used the Ontario building layer from the Ontario Ministry of Natural

Resources (2006). With these data and using ArcMap, we estimated housing density within each watershed. For the U.S., housing unit density per square kilometer was calculated for each census block. The census block data were then combined with the assessment units 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 assessment unit and the total housing density was calculated by dividing the number of houses by total area of each unit in km^2. The ratings for this indicator are not well developed and should be improved.

Invertebrate IBI

KEA (Type): Macroinvertebrate quality (Condition)

Target: Coastal Wetlands

Description: A basin-wide coastal wetland survey project funded by the Great Lakes Restoration Initiative is collecting extensive invertebrate data on all 5 Great Lakes, using methods from Uzarski et al. (2004). This indicator is being developed for SOLEC as the Coastal Wetland Invertebrate Communities indicator (Uzarski and Burton 2011).

Basis for Assessing Indicator: Data from the Coastal Wetland Monitoring project mentioned above is not yet available but should be by early in 2013 to enable a current status assessment. Details on field methods and calculation of the IBI are available in Uzarski et al. (2004). For the purposes of the LEBCS, average invertebrate IBI values could be calculated for each assessment unit. A more nuanced assessment could distinguish particular vegetation zones in each surveyed wetlands (indicator categories differ across zones), but those zones are not distinguished in the LEBCS. This indicator and others being developed by that project team could be updated in 2013 to provide a more complete assessment of the status of Coastal Wetlands in Lake Erie.

Lake sturgeon status across tributaries

KEA (Type): Population size & dynamics (Size)

Target: Native Migratory Fish

Description: Lake sturgeon are dependent upon tributaries and connecting channels for spawning habitat (Lane et al. 1996, Zollweg et al. 2002). Historically, they were an important ecological and economic component of the Lake Erie fish community (Leach and Nepszy 1976, Carlson 1995, Zollweg et al. 2002,, Ryan et al. 2003, Davies et al. 2005). However, their populations were decimated by overfishing, dam construction, and habitat degradation (Ryan et al. 2003, Davies et al. 2005). Recent efforts to build up existing sturgeon populations in the Connecting Channels (Caswell et al. 2004) is proving to be promising (Johnson et al. 2006, Roseman et al. 2011) and this could help restore populations elsewhere in Lake Erie.

Basis for Assessing Indicator: Ratings are based on information in Zollweg et al. (2002). “Large” populations were defined by Zollweg as 1,000 or more in the annual spawning run, which is consistent with the SOLEC lake sturgeon indicator.

Lake trout (catch per unit effort)

KEA (Type): Predator fish species population size (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator is a regularly collected measure by the Coldwater Task Group. Lake trout were an important top predator and much is being invested in their recovery. Lake trout are an indicator of overall ecosystem health

Basis for Assessing Indicator: Compiled by the Coldwater Task Group in their annual reports to the Great Lake Fishery Commission.

Lake trout recruitment (natural)

KEA (Type): Predator fish species population size (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator would show if there is any natural reproduction happening. The goal for lake trout recovery is self-sustaining populations

Basis for Assessing Indicator: Compiled by the Coldwater Task Group in their annual reports to the Great Lake Fishery Commission

Marsh Bird IBI

KEA (Type): Abundance and diversity of wetland-dependent bird species (Condition)

Target: Coastal Wetlands

Description: This indicator captures the status of birds in coastal wetlands. It is the same as SOLEC draft indicator for Wetland Birds (Tozer 2011a), and is part of a Great Lakes basin-wide monitoring project funded through theU.S. EPA Great Lakes Restoration Initiative. It builds upon previous work of the Great Lakes Coastal Wetland Consortium and Great Lakes Environmental Indicators projects (Matthew Cooper, Notre Dame University, pers. comm.).

Basis for Assessing Indicator: We obtained data from Bird Studies Canada, who has coordinated surveys on over 200 marsh routes in Lake Erie for up to 15 years through the volunteer based Marsh Monitoring Program (2009). Using ArcMap, we calculated the average of the Marsh Bird IBI values for all marsh routes in each assessment unit.

Mean annual total phosphorous

KEA (Type): Water quality (Landscape Context)

Target: Coastal Wetlands

Description: Phosphorus is an important measure of trophic state and keeping phosphorus below target levels is important to maintain or achieve trophic conditions (e.g., oligotrophic or mesotrophic, depending upon where you are in the lake) and avoid nuisance and harmful algal blooms (IJC 2012).

Total phosphorus has been measured for decades in the Great Lakes and has been a predominant measure of phosphorus as an indicator of eutrophication, though more recently dissolved phosphorus (or soluble reactive P) has become an increasingly important indicator.

Basis for Assessing Indicator: The ratings for this indicator are limited to the *Good* category, for which the Lake Erie Binational Nutrient Management Strategy (Lake Erie LaMP 2011) recommends a target of one recording of <30 µg/L/year. Total phosphorus is measured regularly in the Nearshore and Open Waters of the Great Lakes, but we did not find good data for Coastal Wetlands.

Mean densities of rotifers, copepods, and cladocerans in early summer (individuals/L)

KEA (Type): Food web linkages (Condition)

Target: Nearshore Zone

Description: The two Dreissena species that have invaded the Great Lakes, zebra mussels and quagga mussels, have caused massive changes in the Great Lakes. In the Nearshore, these have included changes in nearshore nutrient dynamics (Hecky et al. 2004, Bootsma et al. 2012), large outbreaks of nuisance *Cladophora* (Bootsma 2012), degradation of spawning reefs (Marsden and Chotkowski 2001), and eradication of native freshwater mussels from many Great Lakes habitats (Schloesser et al. 1996).

Basis for Assessing Indicator: Ratings were informed by relationships in Nalepa et al. (2009), which indicate that Diporeia densities were already greatly diminished by the time Dreissena densities reached 1000 m-2. Current Status based on Nalepa et al. 2010 and Nalepa et al. 2009.

Mean Dreissena density

KEA (Type): Community architecture (Condition)

Target: Nearshore Zone

KEA (Type): Population size & dynamics (Size)

Target: Connecting Channels

Description: The two *Dreissena* species that have invaded the Great Lakes, zebra mussels and quagga mussels, have caused massive changes in the Great Lakes. In the Nearshore, these have included changes in nearshore nutrient dynamics (Hecky et al. 2004, Bootsma et al. 2012), large outbreaks of nuisance *Cladophora* (Bootsma et al. 2012), degradation of spawning reefs (Marsden and Chotkowski 2001), and eradication of native freshwater mussels from many Great Lakes habitats (Schloesser et al. 1996).

Basis for Assessing Indicator: Ratings were informed by relationships in Nalepa et al. (2009), which indicate that *Diporeia* densities were already greatly diminished by the time *Dreissena* densities reached 1000 m^{-2}. Current Status based on Nalepa et al. 2010 and Nalepa et al. 2009. We did not have data to assign status ranks for the Nearshore Zone or Connecting Channels and recommend surveys to assess the status of this indicator.

Mean growing season (Mar-Oct) water level

KEA (Type): Water level regime (Landscape Context)

Target: Coastal Wetlands

Description: This indicator reflects the importance of water levels during the growing season for the availability of fish spawning habitat and for the vegetation composition of Coastal Wetlands in Lake Erie and Lake St. Clair (IUGLS 2011).

Basis for Assessing Indicator: Ratings for this indicator are based on the IUGLS analysis of restoration options. For Lake Erie, we referred to indicators ERI-01a and EIR-01b, and for Lake St. Clair, indicators LSC-01, LSC-02, and LSC-03 informed the ratings (IUGLS 2011, p 73). We obtained water level data from the National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory (NOAA 2012b) and then graphed these data to evaluate water levels in each of the past five years.

Native mussel abundance

KEA (Type): Population size & dynamics (Size)

Target: Connecting Channels

Description: Freshwater mussels are of significant interest in North American given the high diversity of this taxa in North America and the high level imperilment of this group (Master 1990), as well as the ecological functions they provide (Vaughn et al. 2008). Among these ecological functions is their ability to filter large volumes of water, which helps to temper algal populations in productive areas and helps to reduce turbidity. In addition, their shells provide important habitat for macroinvertebrates and help to stabilize sediments—especially in sandy areas.

Basis for Assessing Indicator: Lake Erie mussel data is limited (EC and EPA 2009), particularly for data that quantified and reported abundances of mussels. Therefore, insufficient information was available to even attempt guessing as to what mussel abundances should be in the Lake Erie Nearshore.

Nitrogen

KEA (Type): Water chemistry (Landscape Context)

Target: Nearshore Zone

Description: Whereas phosphorus is the key limiting nutrient and the focus of management efforts in Lake Erie, nitrogen can occasionally limit productivity and should be the focus of ongoing research (Lake Erie LaMP 2011). As stated in the Binational Nutrient Mangement Strategy (Lake Erie LaMP 2011, p3):

> "*…it is important to continue to research and monitor the effects of nitrogen and other nutrients so that management decisions and actions can be adapted toappropriate concerns.*"

Basis for Assessing Indicator: We did not develop ratings for this indicator, and recommend further research to clarify the role of nitrogen in Lake Erie nutrient dynamics.

Number mature lake sturgeon

KEA (Type): Population size & dynamics (Size)

Target: Connecting Channels

Description: Lake sturgeon have been steadily increasing across the Great Lakes, though no populations are large (Elliott et al. 2011), and their numbers provide a useful and recognizable sign of water quality and habitat improvements.

Basis for Assessing Indicator: Based on work in the Huron – Erie Corridor (e.g., Boase et al. 2011, Thomas and Haas 2004) and expert input, we developed ratings for this indicator that apply well to both the Detroit and St. Clair River and Lake St. Clair. Mike Thomas (Michigan DNR, pers. comm.) has estimated 16,000 adults for lower Lake Huron, St. Clair River, and Lake St. Clair (all one population) and Jim Boase, in a presentation at Great Lakes Week 2011 (10/14/11) cited a breeding population of 5,000 for Detroit River.

Percent coverage of Phragmites

KEA (Type): Species composition / dominance (Condition)

Target: Coastal Wetlands

Description: Experts agreed that the extent of coverage by invasive species is a valuable indicator of the viability of Coastal Wetlands. Non-native, invasive plants occupy space that otherwise would be occupied by native species, and can fundamentally change the structure, composition, and processes of a coastal wetland. Common reed (*Phragmites australis*) is particularly harmful in that it grows in dense monocultures, spreads quickly and widely, and is eaten by virtually no insects or other herbivores. The rating categories are based on expert opinion and are similar to other status ratings based on invasive plants.

Basis for Assessing Indicator: Until recently, only local data or anecdotal information on the coverage of Phragmites--or any invasive plant for that matter--have been available. Recently, the USFWS, USGS, and Michigan Tech Research Institute (MTRI; 2012) has developed a shapefile of Phragmites infestations greater than 1 hectare in size for most coastal areas of the Great Lakes (excepting northern Lake Michigan and a few other areas). Using ArcMap, we overlaid this shapefile (provided as a courtesy by MTRI and USGS) with the Great Lakes Coastal Wetland Inventory shapefile of Coastal Wetlands to assess the percent coverage of *Phragmites* in all wetlands, then calculated the average percentage for each assessment unit.

Percent natural land cover in watershed

KEA (Type): Coastal and watershed contribution (Landscape Context)

Target: Nearshore Zone

KEA (Type): Connectivity among communities and ecosystems (Landscape Context)

Target: Coastal Wetlands

Description: This indicator quantifies the amount of natural land cover within the watershed contributing to a Nearshore Zone reach and is important for Coastal Wetlands as well. 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).

Basis for Assessing Indicator: 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). GIS analysis were conducted in ArcMap to calculate natural land cover for the contributing areas of each assessment unit.

Percent natural land cover on entire island

KEA (Type): Size / extent of characteristic communities / ecosystems (Condition)

Target: Islands

Description: This indicator is primarily based on our best estimate of the amount of natural cover needed to maintain natural processes, including the amount of natural cover needed to maintain populations of area-sensitive breeding species.

Basis for Assessing Indicator: Ratings for this indicator are based on expert opinion and published research (Robinson et al. 1995).

Percent natural land cover within 2 km of lake/shoreline

KEA (Type): Size / extent of characteristic communities / ecosystems (Condition)

Target: Coastal Terrestrial Systems

KEA (Type): Coastal and watershed contribution (Landscape Context)

Target: Nearshore Zone

Description: The literature indicates that alteration of natural land cover within a given area has an impact on natural community condition, ecological processes, and plant and animal population viability (Newmark 1987; Forman 1997). By measuring the percent natural land cover of the Coastal Terrestrial Systems, we are essentially directly measuring coastal habitat fragmentation, and indirectly measuring the condition of coastal natural communities as well as the integrity of coastal natural processes. The effect of conversion of natural landcover within the Coastal Terrestrial System of the Great Lakes has similar impacts on the Nearshore Zone and Coastal Wetlands as land use conversion across the entire watershed, including degraded water quality and impaired biotic communities (Uzarski et al. 2005, Webb 2008). Conversion of natural land cover within a 2 km distance also affects Aerial Migrants (Ewert and Hamas 1995).

Basis for Assessing Indicator: Published studies are insufficient to identify thresholds for percent land cover. For consistency, 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 et al. 2001, Rubbo and Kiesecker 2005, Lougheed et al. (2001), Niemi et al. (2009) and Environment Canada and the Central Lake Ontario Conservation Authority (2004). 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 these relationships is needed.

Percent natural land cover within 500m of mapped wetlands

KEA (Type): Connectivity among communities and ecosystems (Landscape Context)

Target: Coastal Wetlands

Description: This indicator, similar to the one directly above, recognizes the impacts of loss of natural land cover in coastal terrestrial areas on adjacent Coastal Wetlands. There is ongoing work related to stressors to Coastal Wetlands that may suggest modifications to this indicator (Pers. comm., Matthew Cooper, Notre Dame University, August 2011).

Basis for Assessing Indicator: There are no published studies that quantify the relationship between percentage of adjacent natural land cover and condition of Coastal Wetlands, so ratings for this indicator are based on expert opinion and are similar to the ratings for the 2 km natural land cover indicator above. We did not assess the current status of this indicator, recognizing the need for research related to the impacts of land cover change on Coastal Wetlands.

Percent of Accessible Creek Habitat (stream order 2-3)

KEA (Type): Access to Spawning Areas (Landscape Context)

Target: Native Migratory Fish

Description: Since many different species of fish migrate into tributaries in the Great Lakes (Trautman 1983, Herbert et. al. 2012), connectivity to a wide variety of habitats is necessary to maintain populations of all of these species. Stream size is a major habitat component and is correlated with many important physical and chemical habitat variables. (A more comprehensive evaluation of connectivity to a wide variety of habitat types is warranted, but was beyond the scope and capacity of this effort.) Some creeks occur upstream as part of the drainage network of larger rivers, while others flow directly into Lake Erie. Creeks are rivers with a stream order (Strahler 1957) of 2-3.

Basis for Assessing Indicator: GIS analyses were conducted to determine the proportion of creeks within each assessment unit that were connected to Lake Erie (i.e., that were not isolated from Lake Erie by dams). Indicator ratings were quartiles of the proportion of creeks that are currently connected to Lake Erie.

Percent of Accessible Headwater Stream Habitat (stream order 1)

KEA (Type): Access to Spawning Areas (Landscape Context)

Target: Native Migratory Fish

Description: Since many different species of fish migrate into tributaries in the Great Lakes (Trautman 1983, Herbert et. al. 2012), connectivity to a wide variety of habitats is necessary to maintain populations of all of these species. Stream size is a major habitat component and is correlated with many important physical and chemical habitat variables. (A more comprehensive evaluation of connectivity to a wide variety of habitat types is warranted, but was beyond the scope and capacity of this effort.) Headwater streams are the very smallest streams, many of which might be ephemeral. Some headwater streams are located far upstream within the watersheds of major rivers, while others flow directly into Lake Erie. Streams with a stream order (Strahler 1957) of 1 were considered headwater streams.

Basis for Assessing Indicator: GIS analyses were conducted to determine the proportion of headwater streams within each assessment unit that were connected to Lake Erie (i.e., that were not isolated from Lake Erie by dams). Indicator ratings were quartiles of the proportion of headwater streams that are currently connected to Lake Erie.

Percent of Accessible Large River Habitat (stream order >6)

KEA (Type): Access to Spawning Areas (Landscape Context)

Target: Native Migratory Fish

Description: Since many different species of fish migrate into tributaries in the Great Lakes (Trautman 1983, Herbert et. al. 2012), connectivity to a wide variety of habitats is necessary to maintain populations of all of these species. Stream size is a major habitat component and is correlated with many important physical and chemical habitat variables. (A more comprehensive evaluation of connectivity to a wide variety of habitat types is warranted, but was beyond the scope and capacity of this effort.) As the largest rivers in the Lake Erie basin, all large rivers flow directly into Lake Erie. Large rivers are rivers with a stream order (Strahler 1957) of 6 or greater. Many assessment units did not have any rivers this large.

Basis for Assessing Indicator: GIS analyses were conducted to determine the proportion of large rivers within each assessment unit that were connected to Lake Erie (i.e., that were not isolated from Lake Erie by dams). Indicator ratings were quartiles of the proportion of large rivers that are currently connected to Lake Erie.

Percent of Accessible Small River Habitat (stream order 4-5)

KEA (Type): Access to Spawning Areas (Landscape Context)

Target: Native Migratory Fish

Description: Since many different species of fish migrate into tributaries in the Great Lakes (Trautman 1983, Herbert et. al. 2012), connectivity to a wide variety of habitats is necessary to maintain populations of all of these species. Stream size is a major habitat component and is correlated with many important physical and chemical habitat variables. (A more comprehensive evaluation of connectivity to a wide variety of habitat types is warranted, but was beyond the scope and capacity of this effort.) Some small rivers occur upstream as part of the drainage network of large rivers, while others flow directly into Lake Erie. Small rivers are rivers with a stream order (Strahler 1957) of 4-5.

Basis for Assessing Indicator: GIS analyses were conducted to determine the proportion of small rivers within each assessment unit that were connected to Lake Erie (i.e., that were not isolated from Lake Erie by dams). Indicator ratings were quartiles of the proportion of small rivers that are currently connected to Lake Erie.

Percent of Accessible Tributary Wetland Habitat

KEA (Type): Access to Spawning Areas (Landscape Context)

Target: Native Migratory Fish

Description: Some Great Lakes migratory fish, such as northern pike and muskellunge, use tributary systems to access wetland systems located upstream (Trautman 1981).

Basis for Assessing Indicator: Like stream habitat, inland wetland connectivity indicator ratings were based on quartiles of the proportion of the total within each assessment unit that are connected to Lake Erie. There is no data developed to link Great Lakes tributaries to inland wetlands, so we were not able to assess the current status. Instead, the current status is a qualitative best guess based on the status of tributary connectedness within each assessment unit. A future study should develop an analysis of tributary wetland habitat availability.

Percentage of 2 km shoreline area that is suitable for shorebirds

KEA (Type): Habitat availability (Landscape Context)

Target: Aerial Migrants

Description: Studies outside the Great Lakes region indicate that the number and/or species richness of shorebirds is positively associated with the amount of wetland cover at a scale of 3-10 km.

Basis for Assessing Indicator: Based on these findings, we used expert opinion to assign values to the proportion of suitable habitat (see Farmer and Parent 1997, Fairbairn and Dinsmore 2001).

Percentage of 2 km shoreline area that is suitable habitat for landbirds

KEA (Type): Habitat availability (Landscape Context)

Target: Aerial Migrants

Description: Increased densities of migrants occur in habitat patches located in landscapes <40% in natural cover (Williams 2002), especially those landscapes with very low (<10%) cover (Strobl 2010) and mass gains may be reduced in landscapes with less cover (Ktitorov et al. 2008).

Basis for Assessing Indicator: Based on these findings, we used expert opinion to assign values to the proportion of suitable habitat.

Percentage of 2 km shoreline area that is suitable habitat for waterfowl

KEA (Type): Habitat availability (Landscape Context)

Target: Aerial Migrants

Description: Given the relatively high co-occurrence of shorebirds and waterfowl (especially dabbling ducks and geese), and one study done on the Great Plains indicating that the number of one species of dabbling duck during migration was positively associated with the amount of wetland cover (Brennan 2006), we adopted the same measure for waterfowl as shorebirds. Comparable studies have not been done in the Great Lakes region.

Basis for Assessing Indicator: Based on these findings, we used expert opinion to assign values to the proportion of suitable habitat.

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

KEA (Type): Coastal land use (Landscape Context)

Target: Coastal Terrestrial Systems

Description: The literature indicates that alteration of natural land cover in the surrounding landscape has an impact on habitat quality, community structure, species viability, and ecological processes. The quality and type of land cover surrounding particular habitats or natural communities impacts species richness and viability, nest predation, establishment of invasive species, and ecological processes such as seed dispersal, pollination, flooding, and hydrologic fluctuations (Saab 1999; Murcia 1995).

Basis for Assessing Indicator: Little to no literature exists for thresholds of natural land cover in the surrounding landscape. We adopted the same indicator rankings that were used in the Lake Ontario Biodiversity Conservation Strategy (Lake Ontario Biodiversity Strategy Working Group 2009) and Lake Huron Biodiversity Conservation Strategy (Franks Taylor et al. 2010), which were based on information from the following articles and organizations: Dodd and Smith (2003), Findlay et al. (2001), Rubbo and Kiesecker (2005), and Environment Canada and the Central Lake Ontario Conservation Authority (2004).

Percentage of high priority habitat across all bird groups, that is in conservation management

KEA (Type): Management Status (Landscape Context)

Target: Aerial Migrants

Description: This is a conservative approach to ensure there is sufficient habitat at all times during any given and between migration seasons. As with all indicators related to Aerial Migrants, more study is needed to refine threshold values.

Basis for Assessing Indicator: Ratings for this indicator are based on expert opinion. Though we intended to use data being developed through a Great Lakes wide study of stopover habitat, those data were not ready in time for this assessment.

Percentage of high-ranked islands that are in conservation status

KEA (Type): Conservation status (Landscape Context)

Target: Islands

Description: This indicator is based on our assessment of the number of high-ranked islands that would capture most of the best remaining ecological variability within an Assessment Unit.

Basis for Assessing Indicator: Ratings for this indicator are based on expert opinion. Though we intended to use data being developed through a Great Lakes wide study of stopover habitat, those data were not ready in time for this assessment.

Percent or biomass of *Microcystis*, *Anabaena*, and *Aphanizomenon*

KEA (Type): Phytoplankton community structure (Condition)

Target: Nearshore Zone and Open Water Benthic and Pelagic Ecosystem

Description: These phytoplankton are the cyanobacteria species found in toxic blooms. Other related measures could include:

- Extent of HABs as measured by NOAA satellite data (NOAA 2012)
- Frequency of HAB advisories (such as measured by State of Ohio beach water monitoring) (http://ohioalgaeinfo.com/)
- HAB toxin concentrations in intakes at public drinking water treatment plants (Trinka Mount, Ohio EPA, pers. comm. 2012)

Basis for Assessing Indicator: This is a placeholder, a suggested indicator for which we currently do not have a complete source of data, and there is a need for review by experts to determine ratings. "Lake Erie is the most heavily impaired by planktonic HABs, particularly in the last two years where satellite images of extensive surface blooms of Microcystis and other HABs have been posted on many websites (e.g. NOAA). Toxic HABs and their causes are a particular concern and the focus of several recent studies" (Watson and Boyer 2011, pg 1). Investigations of the concentrations of algae biomass in the nearshore water might be used to assess trends in water quality. The University of Toledo has collected algae samples in Maumee Bay and the Western Basin (Chaffin et al. 2011; Bridgeman et al. 2012).

Prey biomass (currently includes smelt, round goby, emerald shiner, gizzard shad (walleye, Central Basin))

KEA (Type): Mid-level prey abundance (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator was included to assess the availability of prey to the top predators.

Basis for Assessing Indicator: This indicator is based on the professional judgment of OMNR fisheries biologists. Actual biomass values could be obtained from the Forage Task Group.

Proportion native prey in biomass (e.g., emerald shiner, lake herring (future))

KEA (Type): Mid-level prey composition (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator was selected based on the idea that we want an increased representation of native species in the prey fish biomass rather than the current status of dominance by two invasive species - round goby and rainbow smelt.

Basis for Assessing Indicator: The rating is based on OMNR fisheries biologists' judgment and a review of catch numbers in the Forage Task Group report for 2010.

Ratio of calanoids/(cyclopoids + cladocerans)

KEA (Type): zooplankton community structure (Condition)

Target: Nearshore Zone, Open Water Benthic and Pelagic Ecosystem

Description: This is a desired indicator for zooplankton community composition (EC and EPA 2009, pg 98) that we did not have adequate data to assess**.** A higher ratio means a changed trophic state, i.e., less eutrophic, or more oligotrophic.

Basis for Assessing Indicator: Not assessed. This is a placeholder indicator that is related to the overall trophic state. EC and EPA (2009; pg. 100) note: "Currently the most critical need is for the development of quantitative, objective criteria that can be applied to the zooplankton indicator. The applicability of current metrics to the Great Lakes is largely unknown, as are the limits that would correspond to acceptable ecosystem health" and "interpretation of various indices is dependent to a large extent upon the sampling methods employed, coordination between these two programs, both with regard to sampling dates and locations, and especially with regard to methods, would be highly recommended." Changes in the ratio are complicated and need further study; declines in cladocerans and cyclopoids "may be related to changes in nutrient levels, phytoplankton composition, exotic species interactions, or fish predation pressure" (pg. 98).

Road density (m road / km^2)

KEA (Type): Connectivity among communities & ecosystems (Condition)

Target: Coastal Terrestrial Systems and Islands

Description: Existing information indicates that the Great Lakes region is spanned by extensive road networks. The construction and maintenance of roads is among the most widespread forms of modification in the United States during the past century (Diamond 1990). Roads have substantial ecological impacts (disrupting wildlife movements and behavior, modifying habitats, altering water drainage patterns, introducing exotic species, and modifying microclimates) 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: Rankings for road density were difficult to obtain from the literature. 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 Ritters and Wickham (2003) and the Eastern Ontario Model Forest (EOMF 2006).

Round goby density (mean catch per hectare)

KEA (Type): Competition (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator was included because although round goby provides forage for top predators, it is disrupting the food web of Lake Erie and preys on native fish eggs.

Basis for Assessing Indicator: The Lake Erie Lake Committee Forage Task Group report offers index values by sampling agency/location (5 total) - these vary, but trends are similar. One expert offered that current levels are *Poor*. We looked at the trend to determine current status.

Spawning/recruitment success of representative coastal wetland spawners

KEA (Type): Spawning habitat quality and accessibility (Condition)

Target: Coastal Wetlands

Description: This indicator would complement the wetland fish IBI indicator, and is more reflective of the role of coastal wetlands as critical spawning habitat for many Great Lakes fish species. Data that are being collected by the basin wide Coastal Wetland survey project could be used to develop this indicator (Matthew Cooper, Notre Dame University, pers. comm.).

Basis for Assessing Indicator: Fish data being collected as part of a basin wide survey of Coastal Wetlands (Uzarski et al. 2005) could be developed for this indicator. Those data were not available for the LEBCS, but should be available beginning in 2013.

Species diversity

KEA (Type): Fish Community Composition (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator would be desirable to have as an overall indicator of ecosystem health and recovery.

Basis for Assessing Indicator: This indicator was not populated with data for this assessment due to lack of sufficient information.

Status of sauger across tributaries

KEA (Type): Population size & dynamics (Size)

Target: Native Migratory Fish

Description: Sauger, which largely spawn in tributaries (Lane et al. 1996, Roseman et al. 2009), were historically an important ecological and economic component of the Lake Erie fish community (Van Meter and Trautman 1970, Leach and Nepszy 1976, Koonce et al. 1996). Sauger may have been extirpated from Lake Erie by the 1960s, but some efforts have been taken to re-establish them (Rawson and scholl 1978). Though rare, small tributary spawning populations persist in Lake Erie—at least in the Huron River (Leonardi and Thomas 2000). Further efforts are being considered to re-establish sauger in

Lake Erie (http://www.outdoornews.com/April-2012/Ohio-attempting-sauger-re-introduction-in-Lake-Erie/).

Basis for Assessing Indicator: The status of sauger populations was based on the proportional estimated abundance of the current population, relative to historic, divided into quartiles for *Poor*, *Fair*, *Good*, and *Very Good* ratings. No lakewide assessment of sauger was available, so a variety of sources were used to determine expected distribution and current status (Goodyear et al. 1982, Leonardi and Thomas 2000, MNFI 2011, Natureserve 2011).

Status of shorthead redhorse across tributaries

KEA (Type): Population size & dynamics (Size)

Target: Native Migratory Fish

Description: Shorthead redhorse are one of several Lake Erie redhorse species that migrate into tributary rivers to spawn (Goodyear et al. 1982). Shorthead redhorse appear to be among the most susceptible of the redhorse species to habitat fragmentation (Reid et al. 2008a) and their population size increases with decreasing fragmentation (Reid et al. 2008b).

Basis for Assessing Indicator: The status of shorthead redhorse populations was based on the proportional estimated abundance of the current population, relative to historic, divided into quartiles for *Poor*, *Fair*, *Good*, and *Very Good* ratings. No lakewide assessment of shorthead redhorse was available, so a variety of sources were used to determine expected distribution and current status (Goodyear et al. 1982, Yoder and Beaumier 1986, Bailey et al. 2003, Carlson and Daniels 2004, Sharma and Jackson 2007, Reid et al. 2008a, Natureserve 2011).

Status of walleye across tributaries

KEA (Type): Population size & dynamics (Size)

Target: Native Migratory Fish

Description: Walleye are very important ecologically and economically in Lake Erie (Ludsin et al. 2001, Ryan et al. 2003, Davies et al. 2005) and tributary spawning populations provide a major component of Lake Erie's walleye population (Lane et al. 1996, Mion et al. 1998, Davies et al. 2005).

Basis for Assessing Indicator: The status of walleye populations was based on the proportional estimated abundance of the current population, relative to historic, divided into quartiles for *Poor*, *Fair*, *Good*, and *Very Good* ratings. The current status of walleye for focal tributaries, as defined in Strange and Stepien 2007, was determined through expert review.

Status of white suckers across tributaries

KEA (Type): Population size & dynamics (Size)

Target: Native Migratory Fish

Description: Spawning runs of white suckers in the Great Lakes are widespread and enormous (Klingler et al. 2003, Burtner 2009, Childress 2010), and almost certainly represent the highest biomass of tributary-spawning migratory fish species across the Great Lakes, at least in contemporary times. Recent research on white suckers is beginning to provide an understanding of the functional role of native migratory fish in the Great Lakes (Flecker et al. 2010, Burtner 2009, Childress 2010) and given the abundance and biomass of their runs, white suckers likely play particularly important functional roles.

Basis for Assessing Indicator: The status of white sucker populations was based on the proportional estimated abundance of the current population, relative to historic, divided into quartiles for *Poor, Fair, Good,* and *Very Good* ratings. No data was available at a broad scale on white sucker spawning runs, so the current status was a best guess based largely on the connected status of the potential spawning habitat.

TDS

KEA (Type): Water quality (Landscape Context)

Target: Connecting Channels

Description: This indicator – Total Dissolved Solids – reflects the combined amount of all inorganic and organic substances contained in a liquid in suspended form. It is commonly used as an indicator of water quality.

Basis for Assessing Indicator: We found little information on which to base ratings for TDS in the Connecting Channels, though experts advised that we adopt it for the LEBCS. SOLEC does not have a comparable indicator, nor does the Detroit River Western Lake Erie Basin Indicator Project. The New York State surface water standards for TDS states that TDS “shall not exceed 200 mg/L and shall be kept as low as practicable to maintain the best usage of waters but in no case shall it exceed 500 mg/L” (URS et al. 2005). In the same report, the Upper Niagara River was found to be within this standard. The St. Clair and Detroit Rivers were both around 160 mg/L in 2005, the most recent data that we found (Great Lakes Environmental Center 2007). These values indicate that TDS could be considered *Good*, though we recommend further refinement of this indicator for use in biodiversity assessments.

Total Phosphorus concentrations (μg/L)

KEA (Type): Water chemistry (Landscape Context)

Target: Nearshore Zone, Connecting Channels, and Open Water Benthic and Pelagic Ecosystem

Description: Phosphorus is an important measure of trophic state and keeping phosphorus below target levels is important to maintain or achieve trophic conditions (e.g., oligotrophic or mesotrophic, depending upon where you are in the lake) and avoid nuisance and harmful algal blooms (IJC 2012). Total phosphorus has been measured for decades in the Great Lakes and has been a predominant measure of phosphorus as an indicator of eutrophication, though more recently dissolved phosphorus (or soluble reactive P) has become an increasingly important indicator. Annex 4 of the GLWQA of 2012 (IJC 2012) includes total phosphorus concentrations and load targets for Lake Erie.

Basis for Assessing Indicator: Data is collected and assessed as part of the Great Lakes Fishery Commission, Forage Task Group (GLFC 2012a), efforts to conduct the Lower Trophic Level Assessment program within Lake Erie, including total phosphorus for offshore sites by basin, 1999-2011. Ratings for the basins are used to determine progress toward goals and trophic status.

Variance in Mar-Oct mean water levels for 30-year rolling period

KEA (Type): Water level regime (Landscape Context)

Target: Coastal Wetlands

Description: This indicator reflects the importance of long term fluctuations in water levels during the growing season for the availability of fish spawning habitat and for the vegetation composition of Coastal Wetlands in Lake Erie and is based on research conducted in the wetlands of Long Point (IUGLS 2011).

Basis for Assessing Indicator: Ratings for this indicator are based on the IUGLS analysis of restoration options. Indicators ERI-03b and EIR-04b provided the ranges in values for this indicator (IUGLS 2011, p 74). We obtained water level data from the National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory (NOAA 2012b) and then graphed these data over thirty years to evaluate the variance in water levels over that time period.

Walleye population (number age 2+) - 5-yr average

KEA (Type): Community architecture (Condition)

Target: Nearshore Zone

Description: Walleye are very important ecologically and economically in Lake Erie (Ludsin et al. 2001, Ryan et al. 2003, Davies et al. 2005) and very highly regarded sportfish and economic attractions in the western and Central Basins and Nearshore Eastern Basin.

Basis for Assessing Indicator: This indicator is based on the population abundance estimates of the Lake Erie Committee's (LEC) Standing Technical Committee (STC), Walleye Task Group (WTG) (GLFC 2012b).

Water clarity (secchi depth)

KEA (Type): water quality (Landscape Context)

Target: Open Water Benthic and Pelagic Ecosystem

Description: Water clarity is an indicator of the overall quality of the water and determines light penetration into the water column, thus greatly affecting primary productive and community composition in the phytoplankton.

Basis for Assessing Indicator: Water clarity has been affected by the zebra and now quagga mussels. In the Central and Eastern basins where offshore habitat is found, the reported levels are within a desired range. Information came from the Forage Task Group annual report.

Water Quality Index (WQI) for wetland quality

KEA (Type): Water quality (Landscape Context)

Target: Coastal Wetlands

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; mostly in Lakes Erie and Huron.

Basis for Assessing Indicator: This Water Quality Index (Chow-Fraser 2006) has been applied to Great Lakes Coastal Wetlands producing accurate measurements of condition, using six categories of relative degradation. We have adopted the rankings used in the Lake Huron Biodiversity Conservation Strategy (Franks Taylor et al. 2010). For Lake Erie, data exist for five of the eleven assessment units that have Coastal Wetlands. More comprehensive water quality data are now being collected as part of the basin-wide Coastal Wetland surveys (Matthew Cooper, Notre Dame University, pers. comm.), and this indicator could be refined based on the findings of that project.

Wetland area

KEA (Type): Size / extent of characteristic communities / ecosystems (Size)

Target: Coastal Wetlands

KEA (Type): Community architecture (Condition)

Target: Connecting Channels

Description: This indicator represents the total area of wetlands in each assessment unit. Wetlands provide multiple critical ecosystem functions and habitat for numerous plant and wildlife species, and the total area of wetlands is a valuable and direct indicator of Coastal Wetland viability for a particular area. Wetlands have, in some parts of Lake Erie, been mostly destroyed by human activities including shoreline alteration, dredging, construction of jetties and marinas, and others (e.g., Manny 2007), but there are few references that cite the amount of coastal wetland loss relative to what would be expected for a particular area.

Basis for Assessing Indicator: For most assessment units, the ratings are qualitative and the evaluation of current status is based on expert opinion or rough guess. We obtained data from the Great Lakes Wetlands Consortium (Great Lakes Coastal Wetland Inventory 2004) to calculate the current total wetland area in each assessment unit. To develop a status rank, experts advised that for most units the current wetland area is *Good*. In some cases, such as the Detroit River (Manny 2007) or Upper Niagara River (Buffalo Niagara Riverkeeper 2012), there are published assessments that enabled establishing quantitative ratings and/or more rigorous current status ranks.

Wetland Fish Index (WFI) of wetland quality

KEA (Type): Fish habitat quality (Condition)

Target: Coastal Wetlands

Description: As used in the Lake Huron BCS, 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). The WFI is essentially an earlier version of the SOLEC indicator of Coastal Wetland Fish Community Health (Sass et al. 2011), being developed for use across the Great Lakes basin.

Basis for Assessing Indicator: We obtained data from Pat Chow Fraser for Lake Erie, and used ArcMap to calculate average values of the WFI for each assessment unit. The ratings follow Seilheimer and Chow-Fraser (2006).

Wetland macrophyte index

KEA (Type): Species composition / dominance (Condition)

Target: Coastal Wetlands

Description: This index was also used in the Lake Huron BCS. Wetland macrophytes are directly influenced by water quality, and impairment in wetland quality can be reflected by taxonomic composition of the aquatic plant community. Croft and Chow-Fraser (2007) developed the wetland macrophyte index 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.

Basis for Assessing Indicator: We used data from Pat Chow Fraser and ArcMap to calculate the average wetland macrophyte index in each assessment unit that contained wetlands that had been sampled, including 6 out of 13 assessment units. We used ratings from Croft and Chow-Fraser (2007). Eventually, the more comprehensive data set being developed by an ongoing survey project should be used.

Wetland Zooplankton Index (WZI)

KEA (Type): Trophic structure (Condition)

Target: Coastal Wetlands

Description: This indicator is based on the work of Lougheed and Chow-Fraser (2002), in which they demonstrated that the WZI could effectively detect water quality improvements.

Basis for Assessing Indicator: Ratings are based on Lougheed and Chow-Fraser (2002). We were not able to obtain data for this indicator, and ongoing surveys do not appear to be sampling zooplankton, so the utility of this indicator for future assessments remains uncertain.

Yellow perch population (number age 2+) - 5-yr average

KEA (Type): Community architecture (Condition)

Target: Nearshore Zone

KEA (Type): Predator fish species population size (Condition)

Target: Open Water Benthic and Pelagic Ecosystem

Description: This indicator is a measure based on a five-year running average of populations as determined by the agencies of the Great Lakes Fishery Commission. Yellow perch are very important ecologically and economically in Lake Erie (Ludsin et al. 2001, Ryan et al. 2003, Davies et al. 2005) and very highly regarded sportfish and economic attractions in the Western and Central Basins.

Basis for Assessing Indicator: This indicator is based on the population abundance estimates of the Lake Erie Committee's (LEC) Standing Technical Committee (STC), Yellow Perch Task Group (YPTG) (GLFC 2012c).

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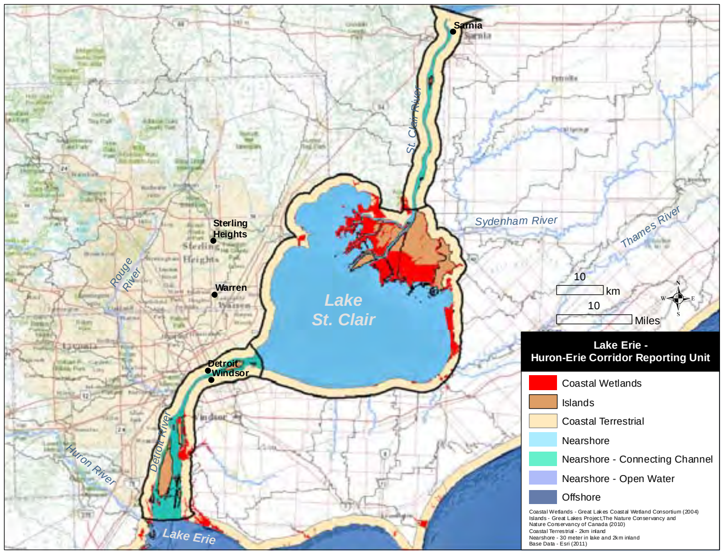
APPENDIX G: REPORTING UNITS: DESCRIPTION, VIABILITY AND THREATS

1) Huron – Erie Corridor



Coastal Area (2 km inland):	7,007 km^2
Shoreline Length:	586 km
Artificial Shoreline:	67%
Cobble Beach:	0%
Sand:	3%
Cliff/Bluff:	1%
Bedrock:	0%

Viability and Threat Summary

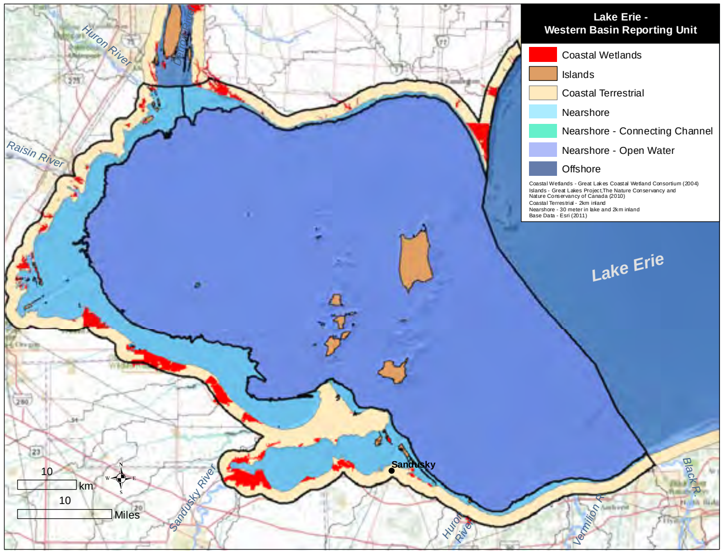
Target	Viability Status	Threat Status
Nearshore Zone	Fair	Very High
Aerial Migrants	Good	Medium
Coastal Terrestrial Systems	Fair	Very High
Coastal Wetlands	Fair	High
Connecting Channels	Fair	Very High
Islands	Fair	High
Native Migratory Fish	Fair	High
Overall	Fair	Very High

Threat Assessment Details

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Connecting Channels	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Invasive Non-Native Aquatic Species		Very High	Medium	Very High	High	Medium	High	Very High
Shoreline Alterations	High		Not Specified	High	High	High	High	High
Pollution: Agriculture sources	Medium	High		High	High	High	High	High
Invasive non-native terrestrial species	Medium	Medium	Medium	Medium	Medium	High	Medium	High
Housing & Urban Development	Medium		Medium	High	Not Specified	High	High	High
Climate change: Habitat shifting & alteration	Medium	Medium	Medium	Medium	High	Medium	Medium	High
Pollution: Industrial sources	Medium	Medium		High	Medium	Medium	Medium	High
Incompatible fisheries management	Not Specified	Medium	Low	Medium	Low	Low	Low	Medium
Pollution: Urban and household sources	Medium	Medium	Low	Medium	Not Specified	Medium	Medium	Medium
Dams & Other Barriers		Medium				Medium	Medium	Medium
Recreational activities	Medium		Low	Low	Low	Medium	Low	Medium
Diking of wetlands		Medium			High	Medium	Medium	Medium
Non-renewable energy	Low			Medium	Medium	Medium	Low	Medium

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Connecting Channels	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Contaminated sediments:	Medium		Medium	Medium	Medium	Medium	Medium	Medium
Navigation & Recreational Dredging & Blasting	Medium	Medium		Medium	Medium	Medium	Low	Medium
Pollution: Airborne sources		Medium			Medium	Medium	Medium	Medium
Mining & Quarrying	Low		Low		Low	Low	Medium	Low
Utility and Service Lines			Low					Low
Dams and Water Management/Use	Medium							Low
Renewable Energy	Low	Not Specified	Medium		Low	Low	Low	Low
Summary Target Ratings:	High	High	Medium	Very High	Very High	Very High	High	Very High

2) Western Basin



Coastal Area (2 km inland):	6,888 km^2
Shoreline Length:	559 km
Artificial Shoreline:	20%
Cobble Beach:	15%
Sand:	3%
Cliff/Bluff:	23%
Bedrock:	5%

Viability and Threat Summary

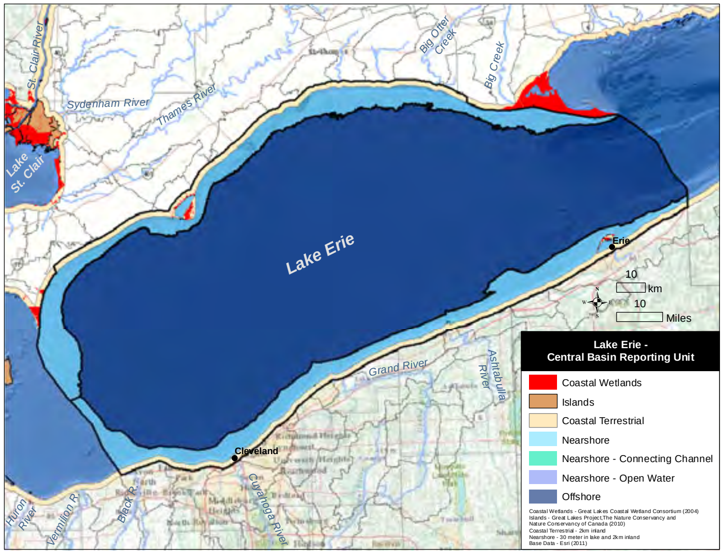
Target	Viability Status	Threat Status
Nearshore Zone	Fair	Very High
Aerial Migrants	Good	High
Coastal Terrestrial Systems	Fair	Very high
Coastal Wetlands	Fair	Very High
Islands	Fair	High
Native Migratory Fish	Fair	High
Overall	Fair	Very High

Threat Assessment Details

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Government Regulations					Very High	Very High	Very High
Shoreline Alterations	High		Not Specified	High	High	High	High
Pollution: Agriculture sources		High		High	High	High	High
Invasive Non-Native Aquatic Species		High	High	High	High	High	High
Invasive non-native terrestrial species	Medium	Medium	High	Medium	High	High	High
Housing & Urban Development	Medium		High	Not Specified	High	High	High
Climate change: Habitat shifting & alteration	Medium	High	Medium	High	High	High	High
Incompatible fisheries management	Not Specified	Medium	Medium	Medium	Medium	Low	Medium
Pollution: Urban and household sources	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Dams & Other Barriers		High		Not Specified	Medium	Medium	Medium
Recreational activities	Medium		Medium	Medium	Medium	Medium	Medium
Problematic Native Species	High						Medium
Diking of wetlands		Medium		Medium	Medium	High	Medium
Non-renewable energy	Low			Low	Medium	Medium	Medium
Pollution: Industrial sources				Medium	Medium	Medium	Medium
Renewable Energy	Medium	Not Specified	Medium	Medium	Medium	Medium	Medium
Contaminated sediments: (should this be incorporated into viability?)	Medium		Medium	Medium	Medium	Medium	Medium

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Navigation & Recreational Dredging & Blasting	Medium	Medium		Medium	Medium	Medium	Medium
Pollution: Airborne sources		Medium		Medium	Medium	Medium	Medium
Mining & Quarrying	Low		Low	Low	Medium	Low	Low
Agriculture: Annual and Perennial Nontimber Crops			Medium				Low
Summary Target Ratings:	High	High	High	Very High	Very High	Very High	Very High

3) Central Basin



Coastal Area (2 km inland):	8,380 km^2
Shoreline Length:	551 km
Artificial Shoreline:	16%
Cobble Beach:	2%
Sand:	18%
Cliff/Bluff:	46%
Bedrock:	6%

Viability and Threat Summary

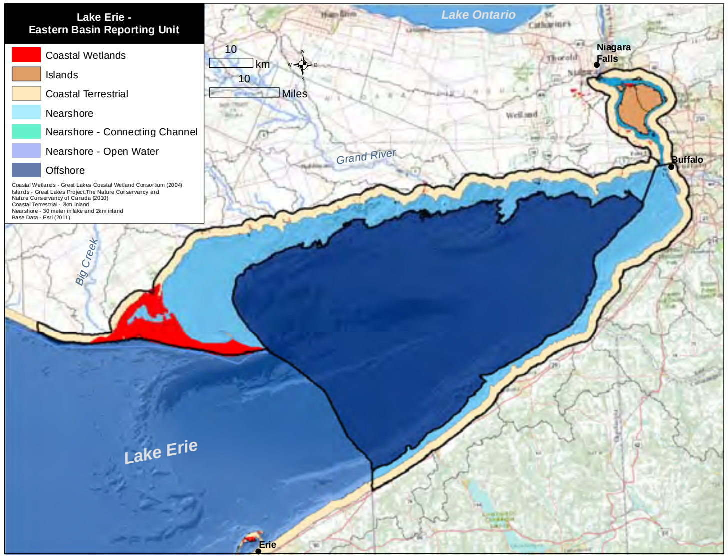
Target	Viability Status	Threat Status
Nearshore Zone	Fair	High
Aerial Migrants	Fair	Medium
Coastal Terrestrial Systems	Fair	High
Coastal Wetlands	Good	High
Islands	Good	High
Native Migratory Fish	Fair	High
Open Water Benthic and Pelagic Ecosystem	Fair	High
Overall	Fair	Very High

Threat Assessment Details

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Pollution: Agriculture sources		Medium		High	Medium	Medium	High	High
Invasive Non-Native Aquatic Species		High	Medium	High	High	High	High	High
Invasive non-native terrestrial species	Medium	Medium	Medium	Low	Medium	High	High	High
Climate change: Habitat shifting & alteration	Medium	Medium	Medium	Medium	High	High	High	High
Incompatible fisheries management	Not Specified	Medium	Low	Medium	Low	Low	Low	Medium
Shoreline Alterations	Medium		Not Specified		High	Medium	Medium	Medium
Pollution: Urban and household sources	Medium	Medium	Medium	Not Specified	Medium	Medium	Medium	Medium
Dams & Other Barriers		Medium			Not Specified	Medium	Medium	Medium
Recreational activities	Medium		Medium		Medium	Low	Low	Medium
Housing & Urban Development	Medium		Medium		Not Specified	Medium	Medium	Medium
Diking of wetlands		Medium			Medium	Medium	Medium	Medium
Non-renewable energy	Medium				Low	Low	Medium	Medium
Pollution: Industrial sources				Medium	Medium	Medium	Medium	Medium
Renewable Energy	Medium	Not Specified	Medium		Low	Medium	Low	Medium

Threats \ Targets	Islands	Native Migratory Fish	Aerial Migrants	Offshore Zone	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Contaminated sediments: (should this be incorporated into viability?)	Medium		Medium	Not Specified	Medium	Medium	Medium	Medium
Navigation & Recreational Dredging & Blasting	Medium	Medium		Low	Medium	Low	Low	Medium
Pollution: Airborne sources		Medium		Medium	Medium	Medium	Medium	Medium
Mining & Quarrying	Medium		Low		Low	Low	Low	Low
Summary Target Ratings:	High	High	Medium	High	High	High	High	Very High

4) Eastern Basin



Coastal Area (2 km inland):	7,328 km^2
Shoreline Length:	1,157
Artificial Shoreline:	14%
Cobble Beach:	3%
Sand:	15%
Cliff/Bluff:	3%
Bedrock:	7%

Viability and Threat Summary

Target	Viability Status	Threat Status
Nearshore Zone	Fair	High
Aerial Migrants	Fair	High
Coastal Terrestrial Systems	Fair	Very High
Coastal Wetlands	Fair	Very High
Connecting Channels	Fair	Very High
Islands	Fair	High
Native Migratory Fish	Fair	High
Open Water Benthic and Pelagic Ecosystem	Fair	High
Overall	Fair	Very High

Threat Assessment Details

Threats \ Targets	Islands	Native Migratory Fish	Offshore Zone	Aerial Migrants	Connecting Channels	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Dams and Water Management/Use		Very High			Very High				Very High
Shoreline Alterations	Medium			Not Specified	High	High	High	Medium	High
Pollution: Urban and household sources	Medium	Medium		Medium	High	Medium	Medium	Medium	High
Pollution: Agriculture sources		Medium	Medium		Medium	High	Medium	High	High
Invasive Non-Native Aquatic Species		High	High	Medium	High	Medium	High	High	High
Invasive non-native terrestrial species	High	Medium	Medium	High	High	Medium	High	High	High
Housing & Urban Development	Medium			Medium	High	Not Specified	High	Medium	High
Climate change: Habitat shifting & alteration	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	High
Contaminated sediments: (should this be incorporated into viability?)	Medium			Medium	High	Medium	Medium	Medium	High
Incompatible fisheries management	Not Specified	Medium	Medium	Low	Medium	Medium	Medium	Medium	Medium
Dams & Other Barriers		Medium				Not Specified	Medium	Medium	Medium

Threats \ Targets	Islands	Native Migratory Fish	Offshore Zone	Aerial Migrants	Connecting Channels	Nearshore Zone	Coastal Terrestrial Systems	Coastal Wetlands	Summary Threat Rating
Recreational activities	Medium			Medium	Medium	Medium	Medium	Medium	Medium
Diking of wetlands		Medium				Medium	Medium	Medium	Medium
Non-renewable energy	Medium				Medium	Low	Medium	Medium	Medium
Pollution: Industrial sources			Medium		High	Medium	Medium		Medium
Renewable Energy	Medium	Not Specified		Medium		Medium	Medium	Medium	Medium
Navigation & Recreational Dredging & Blasting	Medium	Medium	Medium		Medium	Medium	Low	Medium	Medium
Pollution: Airborne sources		Medium	Medium			Medium	Medium	Medium	Medium
Mining & Quarrying	Low			Low		Low	Medium	Low	Low
Summary Target Ratings:	High	High	High	High	Very High	High	Very High	Very High	Very High

APPENDIX H: CLIMATE TRENDS FOR LAKE ERIE, AND IMPLICATIONS FOR BIODIVERSITY

Observed changes in global and regional temperature

Over the last century, the average global surface temperature has increased approximately 0.8^{o}C, with increases of an additional 1.1 – 6.4 ^{o}C or more projected by 2100 (Meehl et al. 2007, Trenberth et al. 2007). In the Great Lakes region, average temperatures for each state have shown increases of between 1 – 1.6 ^{o}C from 1950 to 2009 (Hayhoe et al. 2010). Like other regions at moderate latitudes, climate change projections for the Great Lakes region are somewhat higher than projections for the global average (Christensen et al., 2007). Projections for the Great Lakes region suggest annual increases of 2.0 ± 0.7 °C under lower and 3 ± 1 °C under higher emissions scenarios by the 2050s, and by 3 ± 1 °C under lower and 5.0 ± 1.2 °C under higher emissions by the 2080s (increases are relative to 1961-1990 averages; Hayhoe et al. 2010). These changes are expected to vary geographically, and by season, with the strongest changes expected to be increases in summer maximum temperatures, and winter minimum temperatures (CCSP 2009, Hayhoe et al. 2010). 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. A recent meta-analysis on global estimates for extinction risk by 2100 in response to climate change suggests rates of 10-14% of species across taxa and ecological systems (Maclean and Wilson 2011). .While temperatures on land are rising, we still expect to observe a “lake effect” or moderation of peak summer temperatures in areas adjacent to the Great Lakes relative to other land areas (Scott and Huff 1996). Possibly these cooler areas coastal areas and Great Lakes islands may serve as climatic refugia for species that are highly stressed by increasing summer temperatures. Thus, a strategy of prioritizing conservation and restoration efforts in these could help retain current regional biodiversity by providing a less severe environment for sensitive species. Lake effect areas are also typically warmer than more inland areas in winter, and this effect may even be increased as the amount of ice cover on the lakes continues to decrease. As a result, species that have strong chilling requirements may do less well near the coast, or we may see even more invasives that would typically be killed off by cold winters successfully invading coastal areas.

Temperature as a driver of impacts on Lake Erie

In addition to acting as direct stressor on terrestrial species, increases in air temperature are triggering a whole range of system-wide impacts in the Great Lakes, including decreases in ice cover, increases in water temperature, changes in wind, and increases in the duration of the stratified period (Waples and Klump 2002, Austin and Colman 2007, Austin and Colman 2008, Desai et al. 2009, Dobiesz and Lester 2009, Wang et al. 2011). Recent works documents that in the northern Great Lakes, summer surface water (defined as the upper 30 m) temperatures are increasing even faster than air temperatures (Austin and Coleman 2007). This is because the increases in air temperature also reduce ice cover on the lakes, which sets up a positive feedback on the warming rate of surface waters (Austin and Colman 2007 & 2008, Dobiesz and Lester 2009). 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 & 2008, Dobiesz and Lester 2009). While air temperatures around Lake Erie have also shown increases, the rate of change is lower than in areas further north, and to date no significant trend in summer surface water temperatures been detected, though warming is suggested (Austin and Colman 2007, Dobiesz and Lester 2009). Similarly, while the Great Lakes as a whole have shown a dramatic overall reduction in annual ice area of 77% from 1973-2010 (see Figure 5 and Table 2 in Wang et al. 2011)), the values for Lake Erie and Lake St. Clair, while still high, are at thelow end of the range at 50% and 37% respectively (or - 1.3% and -1.0% yr^{-1}).

The fact that Lake Erie is showing less consistent patterns of summer surface water temperature increase when compared to the larger, more northerly lakes is likely due at least in part to higher variation in ice cover, and less potential for the positive feedback described above. If ice is more variable across years, or simply less common, the positive feedback driving rapid surface water increases is likely to have a weaker effect, leading to a slower rate of increase in a more variable ("noisy") time series. As air temperatures continue to increase, surface water temperatures are projected to keep increasing, but at a slower rate than the other Great Lakes (Table 1, Trumpickas et al. 2009). However, Erie's waters are already the warmest, and this is not expected to change. Further, it is important to remember that increases in ambient temperature often have near exponential effects on physiological processes in aquatic systems, such that smaller changes within a warmer temperatures range can have greater impacts than larger changes within the cooler part of a temperature range.

Table 1: Projected values of peak temperatures (Tmax), and the timing of when surface waters reach 10°C in spring (J10spring), and fall (J10fall) under the IPCC A2 and B2 scenarios, based on projections from the Canadian Global Climate Model Version 2, and under different time periods, for Lake Erie. Tmax is defined as the the 20th highest temperature observed in the lake in a year. Source: Trumpickas et al. 2009, Table 3.

Time period	Scenario	Tmax (°C)	Δ Tmax from Norm	Δ $J10_{spring}$ (Day of the year)	Δ $J10_{spring}$from Norm	$J10_{fall}$ (Day of the year)	Δ $J10_{fall}$ from Norm
1971–2000	Norm	23		136.2		320.6	
2011–2040	A2	24.1	+0.9	125.2	-11.0	327.1	+6.5
2011–2040	B2	24.0	+0.8	124.5	-11.6	327.2	+6.6
2041–2070	A2	24.7	+1.5	115.3	-20.8	335.5	+14.8
2041–2070	B2	24.9	+1.6	118.8	-17.4	333.0	+12.4
2071–2100	A2	26.6	+3.3	101.4	-34.8	346.9	+26.2
2071–2100	B2	25.6	+2.4	112.4	-23.8	338.3	+17.7

In addition to acting as a key factor influencing habitat suitability for fish and other species, temperature drives a key lake process, the timing and duration of stratification. The differences in temperature, light availability, and other factors that occur as a result of stratification provide a diversity of habitats within stratified 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. Given that changes in temperatures for the upper Great Lakes are projected to continue to match or exceed the air temperature increases, we should expect to see even longer stratified periods and increased risk of oxygen deficits below the thermocline in late summer (Magnuson et al. 1997; Jones et al. 2006; Dobiesz and Lester 2009).

As the depth and latitude of a lake, lake basin, or bay decreases, it is less likely to show stratification. The shallow Western Basin of Lake Erie does not consistently stratify in the summer, as the shallow strong winds and shallow depths promote vertical mixing. However, stratification can occur for short periods (e.g., days), and can rapidly produce hypoxia below the thermocline. The Eastern Basin is deeper than the other two, and as a result of these variations in depth and bathymetry, the three basins are often described as functioning as three different lakes. Researchers predict the duration of stratification by estimating when surface waters will go above and below about 4°C (McCormick and Fahnenstiel 1999). Projections for the middle (2050s) and end of this century (2080s) of changes in duration of stratification in Lake Erie suggest that we could see increases in duration of stratification of about month or more by the 2050s, and 1.5-2 months by the 2080s relative to the 1980s (Trumpickas et al. 2009).

Recent work on the temperature dynamics of Lake Erie's Central Basin, which is an area of great concern with respect to current and historical problems with hypoxia, shows a "bowl-shaped" (rather than a dome-shaped) thermocline, which is unusual, and indicates that the colder zone below the thermocline is more compressed than is typical of other lakes (Beletsky et al. 2012), contributing to the high rate of oxygen depletion. This unusual thermocline shape, which the study links to wind patterns, suggests that the drivers that influence the extent and degree of hypoxia may show different relationships in Lake Erie relative to other Great Lakes (Beletsky et al. 2012). This link to wind is important, because warming temperatures in the Great Lakes region can also affect the strength and direction of winds, influencing currents and patterns of stratification. While projections for Lake Erie are not available, observational studies in the region suggest that change may be coming. Recent research on Lake Superior suggests that the rapid rate of summer surface water temperature increases relative to the increases in summer air temperatures has been leading to decrease in the temperature gradient between air and water (Desai et al. 2009). This shift in the gradient is thought to be destabilizing the boundary layer above the lake, and contributing to a 5% increase in wind speed per decade since the mid 1980s (Desai et al. 2009). On Superior, these changes do not appear to be contributing to changes in wind direction, but could potentially be enhancing the effect of warming surface waters on the lengthening of the stratified period (Desai et al. 2009). Work focusing on summer wind direction from 1980-1999 across the Great Lakes shows a statistically significant change in dominant directions around 1990, which the researchers suggest is consistent with a southward shift in the dominant summer storm track (Waples and Klump 2002). The link between changes in the storm track and global temperature increases is likely less direct than the factors leading to changes in wind speed described above, and may be very challenging to predict. While the connections between these observations and key patterns and processes in Lake Erie are likely to be complex, the link in particular between wind patterns, stratification, and hypoxia risks suggests emphasizes the need for improved understanding of wind-related impacts (Waples and Klump 2002, Beletsky et al. 2011).

Changes in precipitation

While temperature increases are expected to accelerate as we continue adding greenhouse gases to the atmosphere, 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 models "agree" on a projection of increases in winter and spring precipitation for the Great Lakes region (Hayhoe et al. 2010). 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. 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 (Mishra et al. 2010b, Trenberth 2011).

Increases in the intensity of peak storms are likely to bring more nutrients into the water that promote algal blooms (Arend et al. 2011). Thus, increased storm intensities is one of several factors (increased temperatures, longer stratified periods) that can contribute to a higher risk of oxygen depletion (hypoxia) in at least the shallow Central Basin of Lake Erie, and possibly in the other basins as well. In this lake in particular, hypoxia is strongly tied to nutrient inputs (phosphorus in particular), which enhance the growth of algae, which contributes to reductions in dissolved oxygen when large amounts die and decompose at the lake bottom. We do expect longer dry periods in the summer as a result of climate change, which may contribute to some reduction in nutrient inputs, and thus reduce the extent or duration of algal blooms in some years.

A key context for thinking about changes in climate, especially changes in extreme storms, is the extent to which natural land cover has been converted in the southern Great Lakes basin. Land cover plays a very important role in determining the water and energy balance of a system, in that vegetation cover slows water down, removes water from the system through evapotranspiration, and influences local temperature due to variations in albedo (reflectance), and by shading the ground surface. When vegetation is removed or shows a major change in composition or structure, such as when forest is converted to agriculture, all of these relationships have the potential to change in ways that increase run-off, and promote flooding (Mao and Cherkauer 2009, Mishra et al. 2010a). The extensive conversion of wetlands in our region has likely dramatically reduced the ability of natural systems to absorb storm impacts, especially in coastal areas like the areas surrounding the western Lake Erie basin that used to be dominated by wetland systems. In a nutshell, many of the threats that dominate our conservation strategies in the Great Lakes are likely to made worse by climate change, and often this is because the natural systems that might be able to buffer some of these impacts have already been significantly degraded.

Changes in lake levels

As a result of changes in temperature, changes in ice cover, and changes in precipitation, lake water levels are also expected to change. In the Great Lakes region, most lake level forecasting has been done using the same basic model (the Large Basin Runoff Model; Croley 1983), which until recently had not been updated to consider how changes in temperature could influence evaporation and related processes (Lofgren et al. 2011). Prior to this update, the most recent forecasts of lakes levels suggested that most GCM projections for future temperature and precipitation would lead to drops in lake levels, although increases were also projected when particular climate models showed strong increases in precipitation (Angel and Kunkel 2010). Work by Angel and Kunkel (2010; values estimated from Figure 5) using 23 GCMs reported a median value for projected changes in Lake Erie by 2050 of about a 0.2 m drop for the high (A2) emissions scenario. However, this work suggested a wide range of possible futures, as the “lowest” 5% of model runs suggest a drop of about 0.9 m or more by 2050, and the “highest” 5% of runs suggest increases of 0.6 m. Similarly, for the high emissions scenarios in the 2080s, Angel and Kunkel’s (2010) work found median values of a 0.3 m decline, with low and high (5^{th} & 95^{th} percentile) values of a 1.1 drop, or 0.5 m increase. Although the Lofgren et al. (2011) paper describing the need to update the tool for modeling lake levels did not do an extensive test of many different GCMs and emissions scenarios, they provide a strong argument that loss of water from evaporation is likely being overestimated when the LBRM is run for future climates, leading to lower rates of run-off into the lakes, and stronger projections of declines. In their tests, comparing their new approach to the old one led to higher potential for lake level increases, or more moderate declines. Specifically, for the 2090s, the new method added roughly 0.6 meters of water to Lake Erie water levels relative to the old method, so final projections for two models were about a 0.6 m drop, or a 0.3 m increase for a drier and wetter set of inputs, respectively (Lofgren et al. 2011). In comparison Hayhoe et al. (2010) presented a value of a 0.4 m drop in Lake Erie’s water level for the same time period using the original version of the model and very high emissions scenario, which might be expected to shift toward a moderate increase of roughly the same magnitude if Lofgren et al.’s (2011) methodological update was employed. As this description suggests, the effects of various inputs and assumptions on lake level modeling is likely to be an active area of research in the next several years.

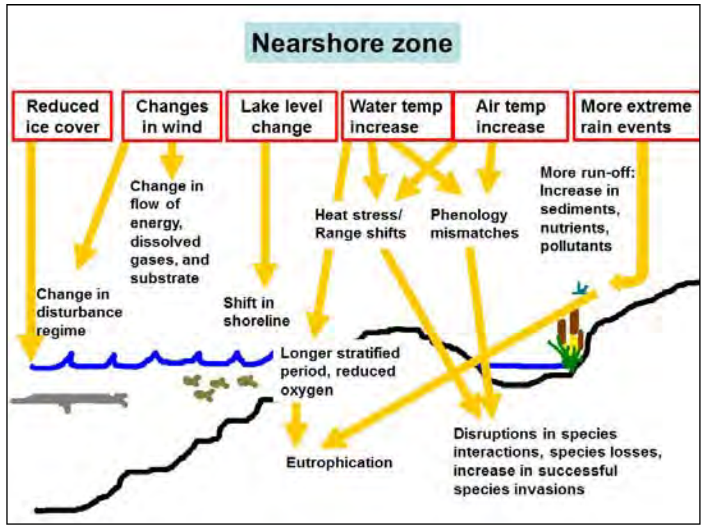
Connecting climate-induced changes to conservation targets

In terms of implications for biodiversity features, the direct impacts of temperature increases are primarily considered a threat because they are happening at such fast rates. 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. As described above in the context of thinking about changes in precipitation, it is important to remember the degraded ecological conditions that often occur in the region as context for assessing vulnerabilities and impacts. For example, a species or system may be much more sensitive to changes in hydrology (timing and amount of water availability) if invasive species, or drainage infrastructure, have already changed the way water moves through the system. Further, it is important to remember that some species and systems will be vulnerable, and others may benefit. While we want to take advantage of any positive effects, we also want to anticipate additional challenges. Specifically, many invasive, non-native species are likely to be more successful at surviving in our region as minimum winter temperatures continue to rise. Even natives from other nearby areas may pose a management challenge as they shift into the region in response to climatic changes; the systems we know are going to change, and we need to have a plan to help facilitate adaptation, while sustaining biodiversity.

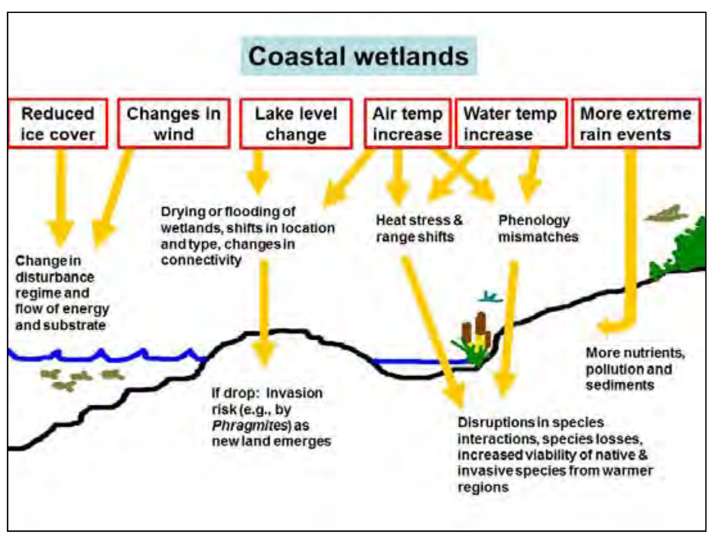
In general, most responses of species to changes in temperature can be categorized as changes in range or local abundance/viability, or as changes in timing of seasonal events (phenology). Changes in species' range boundaries and abundance patterns within the Lake Erie basin are of concern for several 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 (e.g., coastal development, 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, or are flooded an impact that can be accelerated if lake levels change by a sufficiently large amount. Second, species 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 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, such as metamorphosis (e.g., the transition from egg to larvae, or breaking of dormancy for planktonic species). The potential importance of mismatches may be easiest to imagine in systems where attainment of a threshold temperature cues the emergence of leaves of a dominant tree or grass, or algal growth. In such a system, 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 that entire ecological system. If other species in the same system 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.

Nearshore Zone aquatic ecosystems. Key concerns in the Nearshore Zone include impacts related to hypoxia, as warmer water temperatures and a longer stratified period are expected to lead to higher summer oxygen depletion, and more intense storms bring more nutrients into the system to feed algal blooms. 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 habitat types. As noted above, nearshore ecosystems are likely to be impacted by many indirect effects related to more intense storm events, but also are likely to experience increased potential for extended dry periods between rain events, which may reduce connectivity to streams. In particular, nearshore systems are at risk from 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.



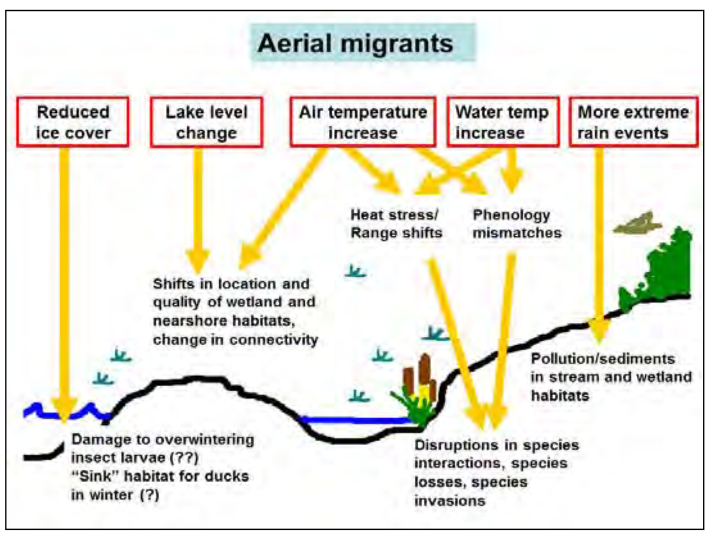
In addition to the aquatic environment, shoreline configuration, seasonal and decadal water level fluctuations, and bedrock geology, climate plays a significant role in structuring and maintaining Coastal Wetlands. Climate change, through warmer air temperatures, increases in evaporation, and changes 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 rapid, strong changes in water levels, resulting in an alteration of the current area, distribution and abundance of coastal wetlands. Areas of greatest concern include places with steep topography or even "drop offs" in the lake bottom (i.e., due to changes in geomorphology), or places where coastal development may limit shifts inland if lake levels increase. More generally, the

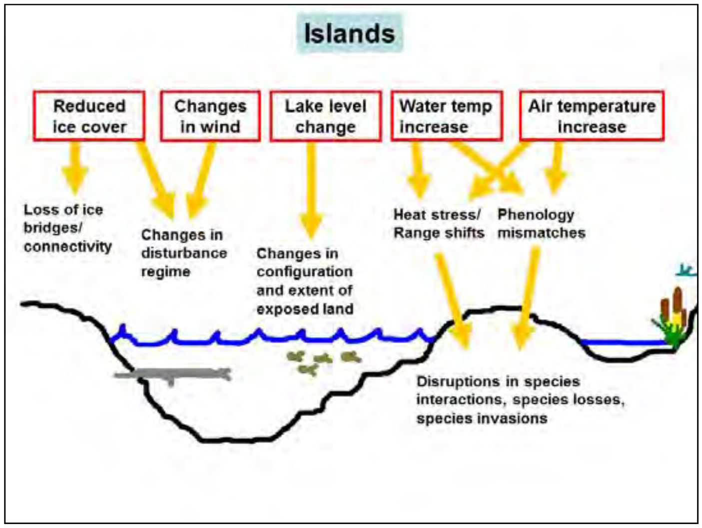


impacts of climate change will potentially exacerbate continuing direct human disturbances such as dredging and filling, water diversion, and pollution from run-off.

Coastal Terrestrial Systems 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/microsite requirements, which, along with the fragmented habitat, suggests high risk from climate change. 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.

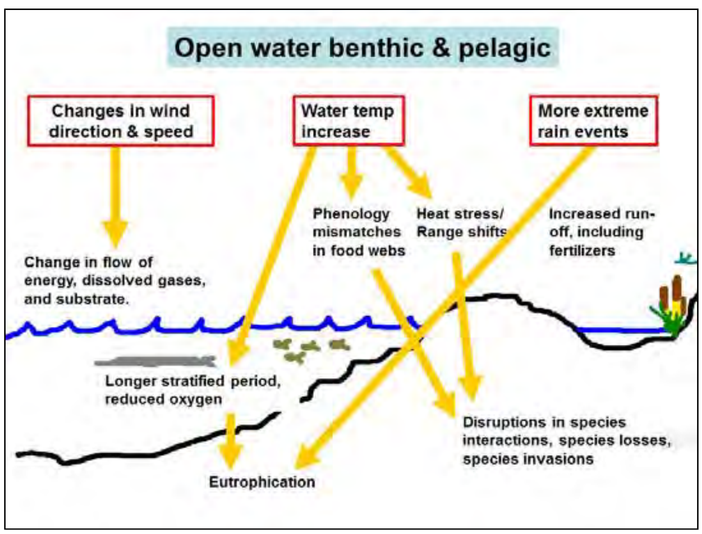
Climate change poses a threat to Aerial Migrants due to loss of key habitats or food resources, and phenology mismatches. Species that require wetland habitats as habitat along their migration route are likely to be most vulnerable, as these habitats are potentially impacted by many different climate 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. 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. 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.



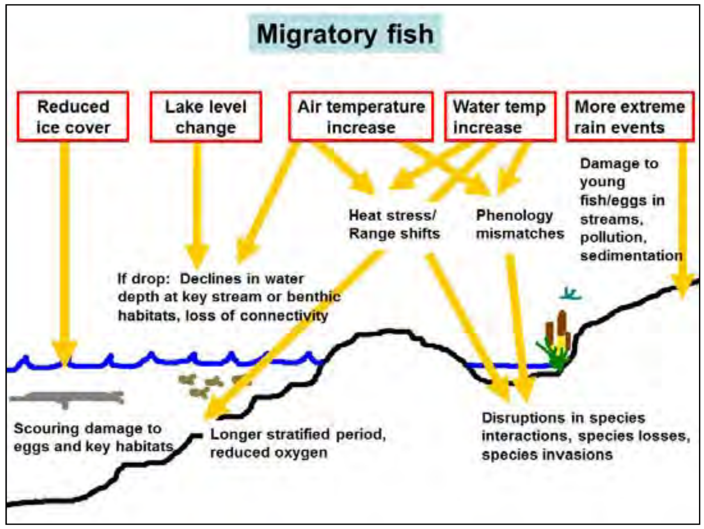


Islands are also expected to be at risk due to climate change impacts, largely due to concerns about the lack of connectivity for species that can't fly or swim (e.g., plants, some insects and reptiles) that would potentially benefit from northward movement. Also, changes in ice cover and duration (e.g., 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 outcompete current native flora or fauna.

Anticipated impacts on the Open Water Benthic and Pelagic Ecosystem 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 Erie are at this point unknown, impacts of this magnitude (e.g., changes on the order of weeks or months) is likely to have a strong impact throughout lake foodwebs (Magnuson et al. 1997).



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 (Magnuson et al. 1997). Even within the same watershed, it is possible to have streams within the same watershed that vary enough in temperature to support different fish assemblages (e.g., cold water, cool water, or warm water fish) due to local variation in geography, and variation in the extent to which the stream is supplied by cold groundwater (Ficke et al. 2007, Chu et al. 2008, Lyons et al. 2010). Thus, understanding patterns of groundwater contribution, and other factors that influence stream temperatures, are likely to be increasingly important for protecting migratory fish during the part of their life cycle spent in these highly sensitive habitats.

Lake Erie Connecting Channels are likely to be susceptible to factors described for the coastal wetlands, and nearshore aquatic systems, especially issues related to changes in water level, and changes in nutrient/pollution inputs. As many of the nested targets in this conservation target are fish, issues related to water temperatures, especially as industrial uses and power plants can also contribute warmed water, are likely to be important. Further, freshwater mussels, another nested target, are suggested to be highly vulnerable to climate change impacts by several expert-based assessments. Factors like limited mobility, strong habitat specificity, and a dependence on one or a few other species during the parasitic phase of their life cycle suggests that there are many drivers that could lead to further population reductions, or reduce the likelihood that restoration efforts will be successful.

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APPENDIX I: GUIDELINES FOR STRATEGY IDENTIFICATION

The strategies were identified and designed during a Workshop following the Conservation Action Planning (CAP) Process that implies the first to complete a situation analysis that describes the relationship among targets, threats, opportunities and stakeholders. This is done through the elaboration of a conceptual model. This is followed by the elaboration of result chains were strategies are linked to chains of factors showing the sequence of the contributing factors affecting threats and ultimately the targets. This Appendix includes the guidelines used during the workshop to develop both, the conceptual model and the result chains. The guidelines are based on TNC (2007) and FOS (2007).

Elaboration of conceptual models

Step 1: Diagram the situation

Core questions: What factors affect the given threat? Who are the key stakeholders linked to each of these contributing factors?

Product: A situation diagram that maps contributing factors (and associated key players) and their relationships with each other and the given threat(s).

Probing Questions:

- What's causing this threat? What factors affect this threat?
- Who are the key players linked to the contributing factor?

Step 2: Brainstorm potential strategies

Core question: What is the most effective way to abate this threat (threat = source + stresses it causes), or multiple threats?

Product: A list of potential strategies that work together to reduce the threat or capitalize on opportunities.

Probing Questions

- At what scale must the threat be addressed to abate it?
- Can the threat be directly reduced at a relevant scale without addressing the driving factors? If not, can the driver(s) be feasibly addressed, or does it represent too strong a force or hurdle? [If so, reassess engagement.]
- Would successful implementation require:
    - Direct protection or management of land/water (e.g., implement prescribed burning)?
    - "Pressure point": Influencing a key decision maker (e.g., amend law that restricts burning)?
    - Addressing a key underlying factor (e.g., provide burn insurance to private landowners)?

Step 3: Select priority strategies

Core question: Which strategies, if implemented, will most effectively and efficiently reduce the threat?

Product: 2-3 priority strategies

Probing Questions:

- Potential Impact: If implemented will it lead to desired changes? This includes two dimensions:
    - probability of positive impact
    - magnitude of change
- Feasibility: Will the project team be able to implement the strategy within likely constraints?
    - Staffing: availability of a lead individual with sufficient time, proven talent, relevant experience, and good institutional support
    - Technical: how straightforward implementation will be, based on complexity and whether such a strategy has been done before (anywhere)
    - Financial: whether difficult without substantial additional resources (if possible, roughly estimate total cost of implementing priority strategies over time horizon of strategy -- i.e., how many zeros?)

Elaborating result chains

A results chain is a diagram with a series of if-then statements that show your logic for how a strategy will lead to a conservation outcome. The results chain focuses on the achievement of results – not the implementation of activities – and it is composed of assumptions that can be tested.

Step 1. Create a results chain for a top-ranked strategy

Core questions: What is your theory of change? What are the key intermediate results and assumptions for successfully implementing your strategy?

Product: A results chain that is results oriented, causally linked, demonstrates change, reasonably complete and simple.

Probing questions:

- Does achieving the result require:
    - Direct protection or management of land/water (e.g., implement prescribed burning)?
    - "Pressure point": Influencing a key decision maker (e.g., amend law that restricts burning)?
    - Addressing a key underlying factor (e.g., provide burn insurance to private landowners)?

Step 2. Identify objectives and indicators for key results

Core questions: What are the key results for which you need specific, measurable outcomes to gage your progress in implementing this strategy?

Product: A set of SMART (specific, measurable, achievable, reasonable, and time bound) objectives with clear indicators to measure progress towards outcomes.

Step 3. Identify Go-no-go results in the chain.

Core questions: Which of these results if not accomplished will require revisiting the strategy and either adjusting it or halting its implementation?

Product: The go-no-go results are identified in the results chain.

Literature cited

FOS 2007 Using Results Chains to Improve Strategy Effectiveness An FOS How-To Guide. Foundations of Success. Improving the Practice of Conservation

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APPENDIX J: ECOSYSTEM SERVICES ASSESSMENT, SCORES AND IMPORTANCE RANKS

Service	Score	Rank
Cultural Services - Recreation and tourism (Lake recreation, wild game, song birds, other wildlife)	163	1
Supporting Services - Provision of habitat (Biodiversity support, habitat diversity)	163	2
Provisioning Services - Fresh Water (Water supply)	162	3
Supporting Services - Primary production (Energy capture, food chain support, energy flow for fish, benthic food chain)	159	4
Cultural Services - Aesthetic values (Aesthetics)	156	5
Supporting Services - Nutrient cycling (Nutrient storage)	152	6
Regulating Services - Water purification and waste treatment (Water quality, waste assimilation, groundwater quality)	151	7
Cultural Services - Sense of place	143	8
Supporting Services - Water cycling (Soil moisture storage)	143	9
Regulating Services - Climate regulation (Carbon storage, moderation of weather extremes)	140	10
Cultural Services - Educational values	138	11
Provisioning Services - Food (Wild game)	136	12
Regulating Services - Water regulation (Flood mitigation)	135	13
Cultural Services - Inspiration	133	14
Cultural Services - Cultural heritage values	129	15
Regulating Services - Erosion control	123	16
Cultural Services - Social relations	115	17
Regulating Services - Storm protection	114	18
Supporting Services - Production of atmospheric oxygen	114	19
Cultural Services - Cultural diversity	106	20
Regulating Services - Air quality maintenance (Air purification, visibility)	106	21
Cultural Services - Knowledge systems	102	22
Supporting Services - Soil formation and retention (Soil renewal, renewal of soil fertility)	101	23

Cultural Services - Spiritual and religious values	98	24
Provisioning Services - Fuel/energy (Hydro-electricity)	96	25
Regulating Services - Biological control (Pest control)	93	26
Regulating Services - Regulation of human diseases	88	27
Regulating Services - Pollination (Pollination)	85	28
Provisioning Services - Genetic Resources	81	29
Provisioning Services - Ornamental Resources	77	30
Provisioning Services - Biochemicals, natural medicines, and pharmaceuticals (Medicines)	56	31
Provisioning Services - Fiber (Timber production)	55	32

APPENDIX K: RELATIONSHIP OF LAKE ERIE BIODIVERSITY CONSERVATION STRATEGIES TO THE GREAT LAKES RESTORATION INITIATIVE ACTION PLAN AND OTHER PLANS AND INITIATIVES

Crosswalk of Lake Erie Biodiversity Conservation Strategies with GLRI Action Plan

Toxic Substances and areas of concern

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	Objectives	Strategies	Objectives
1. Areas of Concern are cleaned up, restoring the areas and removing the beneficial use impairments.	By 2014, delist five Areas of Concern.		
	By 2014, 46 Beneficial Use Impairments (BUIs) will be removed in Areas of Concern.		
2. The release of toxic substances in toxic amounts is prevented and the release of any or all persistent toxic substances (PTS) to the Great Lakes basin ecosystem is virtually eliminated.	By 2011, 15 million pounds of electronic waste and 15 million pills of unwanted medicines will be collected or their release will have been prevented.		
	By 2014, 45 million pounds e-waste, 45 million pills of unwanted medicines, and 4.5 million pounds of household hazardous waste in the Great Lakes basin will have been collected or their release will have been prevented.		
3. Exposure to toxic substances from historically contaminated sources is significantly reduced through source reduction and other exposure reduction methods.	By 2014, 9.4 million cubic yards of contaminated sediments will be remediated.	Promote surface and subsurface drainage options, policies and programs that reduce nutrient losses and delivery.	By 2025, average annual sediment loads reduced by X% in highest priority areas

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	Objectives	Strategies	Objectives
4. Environmental levels of toxic chemicals are reduced to the point that all restrictions on the consumption of Great Lakes fish can be lifted.	Through 2014, an annual average of up to 5% annual decline will be maintained or improved for the trend (year 2000 and on) in average concentrations of PCBs in whole lake trout and walleye samples.		
5. The health and integrity of wildlife populations and habitat are protected from adverse chemical and biological effects associated with the presence of toxic substances in the Great Lake Basin.			

Aquatic Invasive Species

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	Objectives	Strategies	Objectives
1. The introduction of new invasive species to the Great Lakes basin ecosystem is eliminated, reflecting a "zero tolerance policy" toward invasives.	By 2011, eight state ANS management plans will be established or revised to include rapid response capabilities. By 2014, eight state-based, multi-agency rapid response plans will be implemented and 22 mock exercises to practice responses carried out under those plans and/or actual response actions will be completed.	Build political support for policies and regulations that enable more effective control and management of aquatic invasive species.	A minimum of XM/ year is available for aquatic invasive species management from 2013-2020.
			Federal, state and provincial policies and regulations support the control and management of aquatic invasive species by 2015.
	By 2014, a 40 percent reduction in the yearly average rate of invasive species newly detected in the Great Lakes ecosystem will be achieved, compared to the period 2000-2009.	Develop a coordinated framework for aquatic invasive species control/ management for Lake Erie by the end of 2013.	No new aquatic invasive species occur in Lake Erie by 2015.
			By 2020, the range and/or biomass of existing invasive species has been reduced from 2012 levels by 10%.
2. The risk of introduction of species, which are imported for various uses, into the Great Lakes is minimized.	Six technologies that prevent the introduction of invasive species and four technologies that either contain or control invasive species will be developed or refined and piloted by 2011. Ten technologies that prevent the introduction of invasive species and five technologies that either contain or control invasive species will be developed or refined and piloted by 2014.	Demonstrate and quantify results of ecological restoration	By 2015, at least one project has been completed that shows the effectiveness of ecological restoration in controlling and managing aquatic invasive species.
3. The spread of invasive species, by means of recreational activities, connecting waterways, and other vectors, beyond their current range is prevented.			

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	Objectives	Strategies	Objectives
4. A comprehensive program for detection and tracking newly identified invasive species in the Great Lakes is developed and provides up-to-date critical information needed by decision makers for evaluating potential rapid response actions.	By 2011, methodology and protocols will be piloted for the coordinated monitoring methodology and shared protocols for basinwide invasive species surveillance. By 2014, a basinwide surveillance program with shared sampling protocols and methodologies to provide early detection of non-native species will be operational.	Improve coordination of early detection and rapid response of aquatic invasive species.	Develop an Early Detection and Rapid Response plan for Lake Erie aquatic invasive species by 2013.
5. An effective, efficient and environmentally sound program of integrated pest management for invasive species is developed and implemented, including program functions of containment, eradication, control and mitigation.	By 2014, invasive species populations within the Great Lakes Ecosystem will have been controlled and reduced, as measured in populations controlled to a target level in 6,500 acres of managed area and by removing 5,000 pounds of invasive species from the Great Lakes ecosystem.		

Terrestrial Invasive Species

Great Lakes Restoration Initiative Action Plan: Terrestrial Invasive Species		Lake Erie Blueprint	
Goals	Objectives	Strategies	Objectives
1. The introduction of new invasive species to the Great Lakes basin ecosystem is eliminated, reflecting a "zero tolerance policy" toward invasives.	By 2011, eight state ANS management plans will be established or revised to include rapid response capabilities. By 2014, eight state-based, multi-agency rapid response plans will be implemented and 22 mock exercises to practice responses carried out under those plans and/or actual response actions will be completed.	Assemble key regional partners to create a coordinated action plan for Common Reed and other priority terrestrial invasive species by 2013.	By 2015 reduce the total area of Common Reed along the Lake Erie coast by 5%.
		Enhance coordination of outreach and marketing	
	By 2014, a 40 percent reduction in the yearly average rate of invasive species newly detected in the Great Lakes ecosystem will be achieved, compared to the period 2000-2009.		
2. The risk of introduction of species, which are imported for various uses, into the Great Lakes is minimized.	Six technologies that prevent the introduction of invasive species and four technologies that either contain or control invasive species will be developed or refined and piloted by 2011. Ten technologies that prevent the introduction of invasive species and five technologies that either contain or control invasive species will be developed or refined and piloted by 2014.	Coordinate regulation of Common Reed in Canada and the U.S	By 2015 pesticide regulations in Ontario have been updated to allow for more efficient and rapid control of Common Reed.
3. The spread of invasive species, by means of recreational activities, connecting waterways, and other vectors, beyond their current range is prevented.			

Great Lakes Restoration Initiative Action Plan: Terrestrial Invasive Species		Lake Erie Blueprint	
Goals	Objectives	Strategies	Objectives
4. A comprehensive program for detection and tracking newly identified invasive species in the Great Lakes is developed and provides up-to-date critical information needed by decision makers for evaluating potential rapid response actions.	By 2011, methodology and protocols will be piloted for the coordinated monitoring methodology and shared protocols for basinwide invasive species surveillance. By 2014, a basinwide surveillance program with shared sampling protocols and methodologies to provide early detection of non-native species will be operational.	Improve coordination of early detection and rapid response of Common Reed.	By 2015 new colonies of Common Reed are being managed within one year of detection.
5. An effective, efficient and environmentally sound program of integrated pest management for invasive species is developed and implemented, including program functions of containment, eradication, control and mitigation.	By 2014, invasive species populations within the Great Lakes Ecosystem will have been controlled and reduced, as measured in populations controlled to a target level in 6,500 acres of managed area and by removing 5,000 pounds of invasive species from the Great Lakes ecosystem.		

Nearshore health and non-point source pollution

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	**Objectives**	**Strategies**	**Objectives**
1. Nearshore aquatic communities consist of healthy, self-sustaining plant and animal populations dominated by native and naturalized species.	By 2014, a measurable decrease will be achieved in soluble phosphorus loading from 2008 levels in targeted tributaries.	Target and intensify adoption of nutrient management BMPs to reduce dissolved and bioavailable phosphorus loadings to Lake Erie	Based on multi-year averages, reduce the load of dissolved phosphorus by 50% by 2030 in at least the priority watersheds.
			By 20XX, selected KEAs of the Lake Erie nearshore zone improve in response to reduced dissolved phosphorus.
2. Land use, recreation and economic activities are managed to ensure that nearshore aquatic, wetland and upland habitats will sustain the health and function of natural communities.	By 2014, a comprehensive nearshore monitoring program will have been established and implemented, including a publicly accessible reporting system, based on a suite of environmental indicators.	Build a Business Case for Coastal Conservation	By 2022, integrated coastal zone adaptive management plans are created and being implemented across Lake Erie
		Target and intensify adoption of nutrient management BMPs to reduce dissolved and bioavailable phosphorus loadings to Lake Erie	▪By 2014, effective BMPs, including the rate, place, and timing of nutrient applications, for all crops, are better defined and agreed upon. ▪By 2018, 100% of certified retailers are educated in and applying nutrient management following the 4Rs.
		Promote surface and subsurface drainage options, policies and programs that reduce nutrient losses and delivery.	By 2016, 100% of all local, state, federal and provincial personnel who influence drainage programs have received training in water quality and nutrients.

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	**Objectives**	**Strategies**	**Objectives**
3. The presence of bacteria, viruses, pathogens, nuisance growths of plants or animals, objectionable taste or odors, or other risks to human health are reduced to levels in which water quality standards are met and beneficial uses attained to protect human use and enjoyment of the nearshore areas.	By 2014, the causes of nutrient-related nearshore biological impairments will be better understood, and following local or watershed remedial actions, the number and severity of incidences of harmful algal blooms (HABs), avian botulism, and/or excessive *Cladophora* growth will be significantly reduced from 2008 levels.	Target and intensify adoption of nutrient management BMPs to reduce dissolved and bioavailable phosphorus loadings to Lake Erie	▪Identify the source (including urban/residential/other) and transport factors within the HRU that are leading to high P losses ▪ Identify the areas within the HUC/HRU that are the critical source areas. These should be the highest priority for implementing BMPs.
4. High quality bathing beach opportunities are maintained by eliminating impairments from bacterial, algal and chemical contamination; effective monitoring for pathogens; effective modeling of environmental conditions, where appropriate; and timely communications to the public about beach health and daily swimming conditions.	By 2014, rapid testing or predictive modeling methods (to improve the accuracy of decisions on beach postings to better protect public health) will be employed at 33 percent of high priority beaches.		
	By 2014, 50 percent of high priority17 Great Lakes beaches will have been assessed using a standardized sanitary survey tool to identify sources of contamination.	Develop a comprehensive education/ outreach shoreline softening program (Healthy Shorelines)	By 2018, a coastal condition assessment is completed, priority areas for conservation and restoration are identified, and goals and targets for softening and protection are established for priority areas.
	By 2014, 20 percent of high priority Great Lakes beaches will have begun to implement measures to control, manage or remediate pollution sources identified through the use of sanitary surveys.		

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	**Objectives**	**Strategies**	**Objectives**
5. A significant reduction in soil erosion and the loading of sediments, nutrients and pollutants into tributaries is achieved through greater implementation of practices that conserve soil and slow overland flow in agriculture, forestry and urban areas.	By 2014, remediation, restoration and conservation actions in at least one targeted watershed in each Great Lake basin will control erosion, reduce nutrient runoff from urban and agricultural sources, and improve habitat to protect nearshore aquatic resources.	Promote surface and subsurface drainage options, policies and programs that reduce nutrient losses and delivery.	By 20xx, X acres of existing agricultural lands have new or retrofitted drainage water management systems (i.e., modifying any built infrastructure; largely subsurface; NRCS Practice 554, Drainage Water Management (NRCS 2012)) in place in priority watersheds
		Develop a comprehensive education/ outreach shoreline softening program (Healthy Shorelines)	By 2030, Increase current level of ecological connectivity in the coastal zone (or along the shoreline) by an average of 15% compared to 2010 levels (numbers will differ by coastal assessment unit - TBD).
			By 2030, 20% or less of the Lake Erie shoreline will be in hardened condition (numbers will differ by coastal assessment unit)
	By 2014, a baseline will be established for total suspended solids loadings from targeted tributaries.	Promote surface and subsurface drainage options, policies and programs that reduce nutrient losses and delivery.	By 2025, average annual sediment loads reduced by X% in highest priority areas

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	Objectives	Strategies	Objectives
6. High quality, timely and relevant information about the nearshore areas is readily available to assess progress and to inform enlightened decision making.	By 2010, EPA will compile and map the highest priority watersheds for implementation of targeted nonpoint source pollution control measures.	Target and intensify adoption of nutrient management BMPs to reduce dissolved and bioavailable phosphorus loadings to Lake Erie	By 2016, all areas within priority watersheds are identified for focus of farm-based nutrient management efforts. Identify the watersheds / sub-watersheds (Hydrologic Unit Code (HUC))/ hydrologic response units (HRUs) that are contributing the most bioavailable phosphorus (P) to the lake. Targets could be set for either concentration or quantity, or both

Habitat and wildlife protection and restoration

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	**Objectives**	**Strategies**	**Objectives**
1. Protection and restoration of Great Lakes aquatic and terrestrial habitats, including physical, chemical, and biological processes and ecosystem functions, maintain or improve the conditions of native fish and wildlife.	By 2014, 53 percent of populations of native aquatic non-threatened and endangered species are self sustaining.	Increase Connectivity to Lake Erie Focusing on First Barriers	By 2020, there is at least one viable run of walleye in each applicable region of Lake Erie.
2. Critical management activities (such as stocking native fish and other aquatic species, restoring access of migratory fish species at fish passage barriers, and identifying and addressing diseases) protect and conserve important fish and wildlife populations.	By 2014, 4,500 miles of Great Lakes rivers and tributaries will be reopened and 450 barriers to fish passage will be removed or bypassed.	Increase Connectivity to Lake Erie Focusing on First Barriers	▪By 2025 all applicable watershed plans have incorporated the recommendations for addressing barriers generated through the prioritization process ▪By 2020, 25% of all habitat types are connected to Lake Erie
3. Sound decision making is facilitated by accessible, site specific and landscape-scale baseline status and trend information about fish and wildlife resources and their habitats.	By 2014, 97,500 acres of wetlands, wetland-associated uplands, and high priority coastal, upland, urban, and island habitats will be protected, restored or enhanced.		
4. High priority actions identified in strategic plans (such as state and federal species management, restoration and recovery plans, Lakewide Management Plans, Remedial Action Plans, and others) are implemented, lead to the achievement of plan goals, and reduce the loss of fish and wildlife and their habitats.	By 2014, 82% of recovery actions for federally listed priority species will be implemented.	Increase Connectivity to Lake Erie Focusing on First Barriers	By 2015 international management groups (US, Ontario, tribes/first nations) would use the decision tool to set priorities for connectivity restoration across Lake Erie or large sub-regions of the lake. This would include asking groups like the National Fish Habitat Action Partnership (NFHAP) to promote use of the tool.
	By 2014, 30 habitat-related beneficial use impairments will be delisted across the Areas of Concern.		

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	Objectives	Strategies	Objectives
5. Development activities are planned and implemented in ways that are sensitive to environmental considerations and compatible with fish and wildlife and their habitats.	By 2014, 100 percent of U.S. coastal wetlands in the Great Lakes basin will be assessed.	Increase Connectivity to Lake Erie Focusing on First Barriers	By 2016 requests for proposals will reference priority barriers (Great Lakes Restoration Initiative, US Fish and Wildlife Service fish passage program, Canada-Ontario Agreement, Great Lakes Fish and Wildlife Restoration Act, GLFER, NFWF

Accountability, education, monitoring, evaluation, communication and partnerships

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	Objectives	Strategies	Objectives
1. A cooperative monitoring and observing system provides a comprehensive assessment of the Great Lakes ecosystem.	By 2011, a satellite remote sensing program will be implemented to assess Great Lakes productivity and biological (e.g., algal bloom) events.		
	By 2011, a refined suite of science-based indicators for development of a comprehensive assessment of Great Lakes ecosystem health will be identified, monitoring programs for those indicators will begin to be implemented, and restoration and protection actions tied to those assessments and programs assured.		
2. The necessary technology and programmatic infrastructure supports monitoring and reporting, including Great Lakes Restoration Initiative project deliverables by all agencies and participating stakeholders. Data and information are provided in reports that are public friendly, timely and available on the Internet. Reports present integrated and scaled data from watersheds to lakes to Great Lakes basinwide.	By 2011, opportunities for collaboration, planning, data accessibility and accountability will be increased through the expanded use of internet-based technology.		
	By 2011, an Accountability System will be developed and implemented for the Initiative. The system will integrate and make transparent strategic planning, budgeting and results monitoring.		
	By 2014, a statistically valid and comprehensive assessment, using a probability-based design, of Great Lakes water resources, will be established. The system will integrate shipboard monitoring, remote sensing, automated sampling, and other monitoring or observing efforts. By 2016, the system will be in place for all of the Great Lakes and capable of providing a scientifically justifiable assessment of Great Lakes water resources.		

Great Lakes Restoration Initiative Action Plan		LEBCS	
Goals	Objectives	Strategies	Objectives
3. Increase outreach and education for the Great Lakes, and provide ongoing K-12 education for students to understand the benefits and ecosystem functions of the Great Lakes so they are able to make decisions to ensure that restoration investments are enhanced over time.	By 2011, outreach and education efforts are increased, including identifying and revising existing curricula to incorporate sustainable education needs for the Great Lakes that meet state and other relevant learning standards.		
	By 2012, education efforts under existing curricula that meet state and other relevant learning standards will be coordinated across states, and a system for tracking student and teacher outreach (quantitatively and qualitatively) for their use.		
4. Expand the range of opportunities for Great Lakes stakeholders and citizens to provide input to the governments and participate in Great Lakes issues and concerns.	By 2011, social media access opportunities for basinwide public involvement in the Initiative will be in place.		
5. Work under the goals and objectives of the Great Lakes Water Quality Agreement is coordinated between the U.S. and Canada through Lakewide Management Plans (LaMP) and other binational processes, programs, and plans.	By 2012, improved coordination with Canada will take place for programs under the Great Lakes Water Quality Agreement, particularly under the LaMPs, which will result in the achievement of 5-10 priority LaMP goals and actions.		

Related strategies and initiatives

Strategies	Priority Strategies	Related Strategies in other Initiatives
Reducing the Impact of Agricultural Non-Point Source Pollutants	Target and intensify adoption of nutrient management BMP's to reduce dissolved and bioavailable phosphorus loadings to Lake Erie Promote surface and subsurface drainage options, policies and programs that reduce nutrient losses and delivery	▪International Joint Commission, Great Lakes Water Quality Agreement, 2009–2011 Priority Cycle Report on A Near shore Framework ▪International Joint Commission, Great Lakes Water Quality Agreement, IJC Work Group Report on Harmful/Nuisance Algae ▪IJC WQB 2012-2013 Priority Cycle ▪IJC Lake Erie Ecosystem Priority ▪GLRI Action Plan (2010) ▪Lake Erie LaMP, Lake Erie Binational Nutrient Management Strategy ▪LaMP, Lake Erie Nutrient Science Task Group: Status of Nutrients in the Lake Erie Basin(2009) ▪Great Lakes Commission. Priorities for reducing phosphorus loadings and abating algal blooms in the Great Lakes-St. Lawrence Basin ▪Great Lakes Commission. Nutrient Management: A Summary of State and Provincial Programs in the Great Lakes-St. Lawrence River Region ▪State/Provincial and Federal Agriculture Departments promoting and implementing best management practices in key watersheds, including the Maumee, Raisin, Thames and others. ▪Ontario Nutrient Manamgent Act ▪SERA-17 ▪Ohio Lake Erie Phosphorus Task Force Final Report(Phase 1, 2010) ▪The US Army Corps of Engineers-Great Lakes Tributary Modeling Program ▪Ohio Nutrient Reduction Strategy Framework/Directors' Agriculture Nutrient Work Group Report • Lake Erie Millennium Network (LEMN) http://www.lemn.org/ • Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA) • Great Lakes Nutrient Initiative (Environment Canada) • Drainage Act (Ontario – Ministry of Agriculture, Food and Rural Affairs) • Canada-Ontario Environmental Farm Plan

Strategies	Priority Strategies	Related Strategies in other Initiatives
		• Canada-Ontario Farm Stewardship Program • Great Lakes Protection Act and associated Strategy (newly proposed by the Ontario government – Ministry of the Environment) (not yet passed in the Ontario legislature) • Grand River (Ontario) Water Management Plan http://www.grandriver.ca/ • Conservation Authorities' (Ontario) watershed and/or shoreline management plans • Conservation Effects Assessment Program (USDA-NRCS) • State/Provincial and Federal Agriculture Departments and Conservation Authorities (Ontario) or Districts (U.S.) promoting best management practices in key watersheds, including the Maumee, Raisin, Thames, and others. • The Nature Conservancy's Great Lakes Project, Agriculture-Altered Hydrology strategic priority
Preventing and Reducing the Impact of Invasive Species(aquatic and terrestrial)	Terrestrial Strategy 1: Assemble key regional partners to create a coordinated action plan for Common Reed and other priority terrestrial invasive species by 2013.	• Great Lakes Restoration Initiative Action Plan, Invasive Species Goal 5 • Conservation Authorities' (Ontario) watershed and/or shoreline management plans • Several agencies are already managing Common Reed. This includes The Nature Conservancy and U.S. Fish and Wildlife Service in the Ottawa National Wildlife Refuge, Long Point Region Conservation Authority in Long Point (Lee Brown Marsh) and Nature Conservancy of Canada on Pelee Island
	Terrestrial Strategy 2: Coordinate regulation of Common Reed in Canada and the U.S	• Great Lakes Restoration Initiative Action Plan, Invasive Species Goal 5 • Invasive Alien Species Strategy for Canada • Ontario Invasive Plant Strategy • Invasive Phragmites - Best Management Practices 2011 (Ontario). • Cooperative Weed Management Area in WLEB • Conservation Authorities' (Ontario) watershed and/or shoreline management plans
	Terrestrial Strategy 3: Improve coordination of early detection and rapid response of Common Reed.	• Great Lakes Restoration Initiative Action Plan, Invasive Species Goal 4 • Conservation Authorities' (Ontario) watershed and/or shoreline management plans
	Terrestrial Strategy 4: Enhance coordination of outreach and marketing	• Great Lakes Restoration Initiative Action Plan, Invasive Species Goal 1 • OFAH/MNR Invading Species Awareness program

Strategies	Priority Strategies	Related Strategies in other Initiatives
	Aquatic Strategy 1: Develop a coordinated framework for aquatic invasive species control/management for Lake Erie by the end of 2013.	• Great Lakes Restoration Initiative Action Plan, Invasive Species Goal 4 • Great Lakes Ballast Water Program • Conservation Authorities' (Ontario) watershed and/or shoreline management plans
	Aquatic Strategy 2: Build political support for policies and regulations that enable more effective control and management of aquatic invasive species.	• Great Lakes Restoration Initiative Action Plan, Invasive Species Goal s 4 and 5 • Conservation Authorities' (Ontario) watershed and/or shoreline management plans
	Aquatic Strategy 3: Improve coordination of prevention, early detection and rapid response of aquatic invasive species.	• Great Lakes Restoration Initiative Action Plan, Invasive Species Goals 1 and 4 • Department of Fisheries and Oceans Centre of Expertise for Aquatic Risk Assessment • Conservation Authorities' (Ontario) watershed and/or shoreline management plans
	Aquatic Strategy 4: Demonstrate and quantify results of ecological restoration	• Great Lakes Aquatic Nuisance Species Information System (GLANSIS) • Asian Carp Control Strategy Framework • Conservation Authorities' (Ontario) watershed and/or shoreline management plans
Coastal Conservation: Preventing and Reducing the Impacts of Incompatible Development and Shoreline Alterations	Build a Business Case for Coastal Conservation	• Great Lakes Restoration Initiative Action Plan, Near shore goal 2, Habitat goal 3 • Lake EMichigan BCSBiodiversity Conservation Strategy:: Coastal Conservation–Develop and Implement coordinated planning efforts that effectively address the long-term viability of coastal conservation targets. • Ohio Lake Erie Commission Balanced Growth Initiative. • Grand Lake St. Marys Ohio: residents created a strategic plan regarding water quality that was promoted to new Governor and administration, who adopted recommendations and are implementing corrective actions. • Great Lakes Compact in Ohio—initial standards were not accepted by many stakeholders, who were able to convince administration to revise standards in light of international agreement. • Conservation Authorities' (Ontario) watershed and/or shoreline management plans • The "NOAA Report on the Ocean and Great Lakes Economy of the United States" examines the economic contributions of the oceans and Great Lakes. The report

Strategies	Priority Strategies	Related Strategies in other Initiatives
		presents data from the NOAA Coastal Services Center's Economics: National Ocean Watch (ENOW) dataset. A variety of visual representations of the data are included for the national, regional, and state levels • Ontario's Proposed Great Lakes Protection Act and Draft Strategy. • Various Great Lakes St. Lawrence Cities Initiative publications and resolutions • Federal, state/provincial, and watershed and shoreline management (e.g. Ontario Conservation Authorities) agencies , municipalities and Great Lakes St. Lawrence Cities Initiative
	Develop a Comprehensive Education/ Outreach Shoreline Softening Program	• Great Lakes Restoration Initiative Action Plan, Near shore goal 2, Habitat goal 3 • Lake Erie Michigan Biodiversity Coastal Strategy: Coastal Conservation– Develop and Implement coordinated planning efforts that effectively address the long-term viability of coastal conservation targets • Ohio Coastal Management Program – Web-based coastal atlas that provides spatially based information on a variety of coastal activities and natural features • Michigan Sea Grant – has lead and helped implement several shoreline softening projects on or near the Detroit River Rivers International Joint Commission has established the International Great Lakes-St. Lawrence River Adaptive Management Task Team to develop a detailed basin-wide adaptive management plan for addressing future water level extremes. Part of their work plan is to try to initiate (if the opportunities present themselves) some risk assessment pilot studies, so there could be some synergies. • Ontario's Proposed Great Lakes Protection Act and Draft Strategy • Conservation Authorities' (Ontario) watershed and/or shoreline management plans and permit approval processes for shoreline protection measures and implementation of shoreline softening projects
Reducing the Impacts of Urban Non-Point Source and Point Source Pollutants	Improve Storm Water Management	• The report "Delisting Targets For Fish/Wildlife Habitat and& Population Beneficial Use Impairments for The Detroit River Area of Concern" (Schrameck et al. 2009) lists several initiatives and activities related to cleanup of contaminants and reductions in pollution sources in the Detroit River AOC: • Canada-United States Strategy for the virtual elimination of persistent toxic substances in the Great Lakes basin

Strategies	Priority Strategies	Related Strategies in other Initiatives
		• Great Lakes Restoration Initiative Pollution Prevention grants: • Great Lakes United study: “Improving Water Management in the Great Lakes Basin” funded through the Great Lakes Protection Fund. This six-month study seeks “…to identify the ecological benefits and explore the financial rationale for pursuing water conservation and green infrastructure practices, and test how this information—when combined with effective knowledge transfer techniques—can drive better water management throughout the Great Lakes region.” • Ontario’s Proposed Great Lakes Protection Act and Draft Strategy: • Ontario’s Water Opportunities Act strengthens water efficiency and sustainable water planning for municipalities • - A current resource of information is "Health, Prosperity and Sustainability: The Case for Green Infrastructure in Ontario” which is co-authored by the Green Infrastructure Ontario Coalition and Ecojustice. The report draws on input from diverse stakeholders and existing research to present a strong case for improved policies and investments to support green infrastructure in the province. • - Various Great Lakes St. Lawrence Cities Initiative publications and resolutions Conservation Authorities’ (Ontario) watershed and/or shoreline management plans • Great Lakes Restoration Initiative Action Plan, Toxics goal 2 • The Southeast Michigan Council of Governments. This project began in October 2011 and is on schedule to be completed in March 2014. SEMCOG is engaging stakeholders through Task Force and topic-specific resource teams and visioning workshops; defining green infrastructure for Southeast Michigan; benchmarking the state of green infrastructure in the region in terms of benefits, including impacts on water, air, land, and the economy; determining the future of green infrastructure in the region; and will provide recommendations on how to achieve the vision. • Conservation Authorities’ (Ontario) watershed and/or shoreline management plans
Improving the Habitat Connectivity by Reducing the Impact of Dams and Other Barriers	Increase Connectivity to Lake Erie Focusing on First Barriers	• Lake Erie LaMP Objectives 1 and 6. • Great Lakes Fisheries Commission Lake Erie Environmental Objectives. • Great Lakes Restoration Initiative Action Plan, Habitat goal 2 • Conservation Authorities’ (Ontario) watershed and/or shoreline management plans